DOCUMENT RESUME

ED 401 131 SE 059 200

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TITLE	Equity in the Reform of Mathematics and Science Education: A Look at Issues and Solutions.
INSTITUTION	Southwest Educational Development Lab., Austin, TX. Southwest Consortium for the Improvement of Mathematics and Science Teaching.
SPONS AGENCY	Eisenhower Program for Mathematics and Science Education (ED), Washington, DC.
PUB DATE	Sep 94
CONTRACT	R168R20003-94
NOTE	189p.; For the Executive Summary, see SE 059 199.
AVAILABLE FROM	Southwest Educational Development Laboratory, 211 E. 7th Street, Austin, TX 78701-3281.
PUB TYPE	Information Analyses (070)
EDRS PRICE	MF01/PC08 Plus Postage.
DESCRIPTORS	Academic Achievement; *Educational Change; *Educational Equity (Finance); Educational Strategies; Elementary Secondary Education; *Equal Education; Literature Reviews; *Mathematics Education; *Science Education; Teacher Education

ABSTRACT

The current push for reform in mathematics and science education cannot succeed unless it addresses the critical and persistent issue of equity. This report reviews the literature regarding that issue. Its purpose is to provide a reference tool for those who are working to change educational policy and practice. Part 1 of the review discusses the importance of equity--the moral, social, and economic imperatives for assuring educational success for all students. This section also describes the multiple meanings of the term equity as it is used in the educational literature. Part 2 explores a range of equity issues, from the structure and financing of schools to teacher training, expectations, and classroom practice. Part 3 describes educational strategies designed to broaden student success. The conclusions in Part 4 call for a transformation in the structures of U.S. schooling. (Author/JRH)

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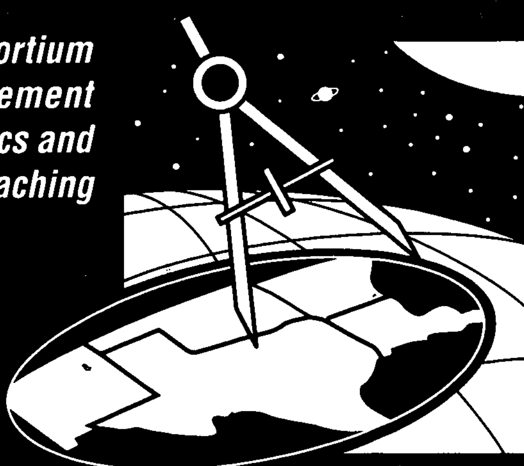

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Edited by Martha Boethel

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Southwest Consortium for the Improvement of Mathematics and Science Teaching

A project of the Southwest Consortium for the Improvement of Mathematics and Science Teaching (SCIMAST) of the Southwest Educational Development Laboratory (SEDL)

September 1994

The Southwest Consortium for the Improvement of Mathematics and Science Teaching (SCIMAST) is one of ten Eisenhower Mathematics and Science Regional Consortia established by the U. S. Department of Education. SCIMAST supports systemic reform through a variety of activities and services: by offering and supporting professional development, by helping states develop a vision of mathematics and science education, and by encouraging the use of appropriate instructional materials, methods, and assessments that support educational reform. SCIMAST activities are grounded in the belief that systemic reform requires support from all educational stakeholders and that the critical voice in reform is that of teachers.

SCIMAST was funded in the fall of 1992 through a 3-year grant, grant number R168R20003-94, from the U. S. Department of Education's Eisenhower National Program for Mathematics and Science Education. Third year funds for SCIMAST total $1,348,100, representing 75 percent of the project's cost. An additional $449,367 is provided from non-federal sources, making up 25 percent of project costs. SCIMAST is operated by the Southwest Educational Development Laboratory (SEDL) as part the Center for the Improvement of Teaching in Mathematics and Science (CITMAS). SEDL has served the Southwest regions (Arkansas, Louisiana, New Mexico, Oklahoma and Texas) since 1966.

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Executive Summary

Equity in the Reform of Mathematics and Science Education

OVERVIEW

The current push for reform in mathematics and science education cannot succeed unless it addresses the critical and persistent issue of equity. This paper reviews the literature regarding that issue; its purpose is to provide a reference tool for those who are working to change educational policy and practice.

Part 1 of the review discusses the importance of equity — the moral, social, and economic imperatives for assuring educational success for all students. This section also describes the multiple meanings of the term *equity* as it is used in the educational literature. **Part 2** explores a range of equity issues, from the structure and financing of schools to teachers' training, expectations, and classroom practice. **Part 3** describes educational strategies designed to broaden student success. The conclusions in **Part 4** call for a transformation in the structures of U.S. schooling. While this executive summary follows the general outline of the full text, some subsections have been collapsed or resequenced for brevity's sake.

Any literature review is limited by the material available. The literature on educational equity is both substantial and meager: We found a great deal of conceptual discussion and descriptions of experience, but limited empirical research, particularly regarding strategies in mathematics and science. We also found far more studies relating to female and to African-American students than to other student populations. In some instances writers used the categories of "minority" and "poor" students as equivalents, an error that compromises their conclusions. The broader literature of mathematics and science reform, which seeks to improve learning for *all* students, seems to address equity issues in promising ways; however it, too, lacks a substantial empirical research base. Finally, it should be noted that these limitations in the literature themselves constitute an equity issue.

PART 1:

What Is Equity? Why Is It Important to Everyone?

Definitions of equity. Discussions of equity in mathematics and science education tend to focus on specific populations: women, African Americans, Hispanics, Native Americans, and speakers of nonstandard English or with limited English proficiency. Additional groups sometimes included are students in rural schools, in lower socioeconomic groups, and with different physical and mental abilities.

Regardless of the particular groups being addressed, people use the term "equity" to mean different things. The way the term is defined has great implications for the ways in which issues are examined and solutions are devised. Definitions in the literature include:

Equity as physical access. This definition is a common, traditional view of equity; it is essentially negative, requiring only that students not be prevented from gaining access to schools, class, media, or materials.

Equity as inclusion or capacity building. "Inclusion" is a term used by Neil (1992) to move beyond the mere opening of doors. Equity as inclusion involves not only access but transforming instructional content and approaches to address each student's individual interests and needs. Similarly, Payzant and Wolf (1993) see equity as "enabling" students; they use student outcomes as the measure of equity rather than "the simple arithmetic of inputs" such as the racial mix of a class or teaching staff. With this perspective, the focus is on assuring that each student acquires whatever educational tools she or he needs to succeed after graduation.

Equity as multiculturalism or diversity. Much of the literature reflects the belief that equity cannot exist without diversity — among teachers, students, curricula, and instructional approaches. However, people use the term "diversity" with multiple meanings. Both Hilliard and Banks (1991-1992) criticize narrow uses of the term, the token additions of multicultural materials or ideas; they emphasize the need to foster diversity in thought and belief. Their focus extends from specific multicultural content to a way of thinking that perceives knowledge as "constructed" by people and cultures and that encourages thoughtful examination of all ideas and beliefs.

Equity as special services. Some educators equate equity with special services for particular groups, for example children with disabilities or students from specific racial, ethnic, or socioeconomic groups. Such services range from special classes to mentoring projects to extracurricular offerings. The literature, however, makes clear that "special treatment" — tracking, for example — can be used to perpetuate inequities as well as to alleviate them.

SEDL's Southwest Consortium for the Improvement of Mathematics and Science Teaching, which sponsored the development of this literature review, defines equity in the most inclusive terms possible. From this perspective, equity means that each student will be addressed as an individual, with instructional opportunities, content, and approaches that meet his or her specific needs, strengths, and interests. All students will be engaged in meaningful learning, in a school environment that values differences and encourages students to participate actively in the learning process.

The imperatives for equity in mathematics and science education. As a number of sources have noted, mathematics and science education has been structured as a pipeline, designed to filter out the majority of students while channeling those who are perceived as most proficient into advanced classes, university programs, and careers. However, a number of forces have converged to render obsolete the traditional view that science and mathematics education is only for an elite few. In an increasingly complex, technological world, a system that emphasizes the production of physicists at the expense of a mathematically and scientifically literate "laity" is failing in major ways. More and more public policy decisions, from genetic engineering to medical research priorities to the protection of habitats, depend on a knowledgeable electorate. Most observers project that long-term changes in the work force will require skills and understandings for which most students are now unprepared. Finally, equity is a moral as well as a public policy and economic issue. Science and mathematics are culturally valuable components of knowledge that should be available to all.

PART 2:

Issues Involved in Equity

The structure of schooling. By its very structure, schooling denies some students opportunities in science and mathematics. The tracking system used in many schools, other structures influencing course access, and fiscal structures that determine a school's access to resources all affect student opportunities.

High track, low track. Students from minority groups are seven times more likely than white students to be identified as having low abilities and, thus, to be placed in low-track classes. Low-track classes spend more time on class routines and discipline and less time actively learning the subject matter. These classes offer more rote instruction and fewer opportunities to use critical and independent thinking skills; instruction is characterized as "oversimplified, repetitive, and fragmentized" (Oakes, 1990b, p. 89). Students who are shunted to low track courses are generally denied access to so-called gatekeeper courses, which prepare them for college-level mathematics and science classes.

Research indicates that high achievers do just as well in a mixed ability class as they do in a high track class, and that heterogeneous groups are more fruitful for teachers and students alike (Oakes, 1990b; NCTM, 1991). There appears to be no valid educational reason for tracking systems. Several educational observers have noted that tracking maintains and reproduces the existing class structure of U.S. society. Joseph Conforti (1992) links tracking to the cultural belief in American society as "a contest society"; whenever a contest is accepted as the basis of interaction, inequality is also accepted.

Access to courses for gifted students. Many schools offer separate classes or groupings within classes for gifted students. However, access is not proportionately distributed across the student population. Educators and parents tend to construct mental images of gifted students — images reflecting the characteristics of white, middle-class students — that can blind them to the actual abilities of children from minority, poor, and other underrepresented groups. For example, one Texas-based study indicates that Hispanic children who are identified as gifted tend to be more acculturated to mainstream U.S. culture than are other Hispanic children (*Education Week*, 26 May 1993). According to most of the literature, educators will more accurately identify gifted students if they move away from traditional criteria, such as standardized tests, and "use multiple assessment procedures, including objective and subjective data from a variety of sources" (Maker, 1989, p. 295). Educators should use culturally and linguistically appropriate assessments and more than one identifying source.

Access to special education. Enrollment in special education is disproportionately high for boys and for African-American and Hispanic students. In 1988, two-thirds of all students in such programs in the United States were male, in spite of the fact that medical reports of learning disabilities and attention-deficit disorders are almost equally divided between boys and girls. Mercer (cited by Mehan, 1992, p. 12) found that students who test the same on objective tests are often treated differentially; she found that "White, female, middle-class students who scored 80 or below were more likely to be retained in regular academic programs than were Black, male, lower-class students who scored the same on the IQ test."

Access to appropriate counseling and advising. The use of vocational-interest tests that have sex-specific norms may help to discourage female students from focusing on mathematics and science. These tests are used by counselors to advise students about courses and career choices. Counselors are more likely to inform a male who does well on such tests about engineering careers than they are to inform females in similar situations. Counselors also tend to steer students with disabilities away from science classes because they often believe the students cannot function in a laboratory. Students from minority and lower socio-economic groups often have less access to counselors; their schools usually have fewer counselors than schools with predominately white, middle-class student populations (Oakes, 1990a).

Resource inequities. Recent studies cast doubt on research conducted in the late 1970s and 1980s, which found that a school district's level of spending had little effect on educational results for each child. A reanalysis of the data used in this older research has led researchers to conclude that, while money may not answer all school problems, "we find that money *does* matter after all" (Hedges, Laine, & Greenwald, 1994, p. 13).

Wealthy school districts often have low tax rates and still spend a higher amount on each pupil than poorer districts with limited tax bases. In Texas, for example, in 1985-86 the 100 poorest districts had an average property tax rate of 74.5 cents and spent an average of $2,978 on each student. The 100 wealthiest districts, in contrast, had an average property tax rate of 47 cents and spent an average of $7,233 on each student (Mauzy, 1989).

Resource problems are often more basic than a need for calculators and balance scales. Many older schools and schools in low-income districts lack adequate electricity, roofs that hold out the rain, adequate sewage facilities, and other basic physical requirements. The use of technology in mathematics and science is not realistic for many inner city and rural schools. How, for example, can a classroom with two electrical outlets and no telephone lines run computers or use telecommunications technology?

Teacher expectations and behaviors. Teachers remain at the core of equity issues; teacher expectations and behaviors are a major influence on equity in U.S. schools. Teacher perceptions of students can be colored by cultural expectations, stereotypes, and inaccurate knowledge gleaned from previous experience. These perceptions and the ways in which teachers express and act upon them influence student learning.

Teachers' fears and expectations. Studies suggest that students' success or failure in the classroom can be strongly influenced by "teachers' beliefs, attitudes, behaviors, and perceptions" (Garibaldi, 1992, p. 31). Teachers often have a white middle-class student's behaviors and goals as their ideal of a good student (DeMott, in Holt, 1992). Teachers often assume that children who have not yet mastered English cannot be taught mathematics or science (Gibbons, 1992a). If a student does not speak English, speaks English in a nonstandard way, or comes from a culture with different behavioral patterns of interaction — such as those regarding eye contact, for example — a teacher may see that student as less capable or less receptive (Garibaldi, 1992; Irvine, 1992). Studies have found that teachers interact differently with students for whom they have higher expectations. For these students they offer more praise for correct answers and less criticism for incorrect answers (Brophy & Good, 1974). Oakes (1990a) reports that teacher expectations also affect the amount of material taught to a class or student.

Studies show that teachers, both female and male, accept cultural assumptions that girls are not interested in science. In all subjects, teachers tend to have lower expectations for girls than they do for boys. They tend to make eye contact with boys more frequently than with girls; in general they show more attention to boys. In their comments about boys' work, teachers tend to focus on the ideas and concepts contained in the work, while their comments about girls' work often center on its appearance (American Association of University Women, 1993).

Teacher education. Teacher education may actually do little to help teachers alter their behaviors and expectations. Most teacher education still neglects issues of equity; preservice classes that do cover these issues appear to do so poorly (Zimpher & Ashburn, 1992; Howie & Zimpher, 1989).

One study (McDiarmid, 1990) of multicultural teacher preservice education indicates that such training made no difference in teachers' rejection or acceptance of stereotypes; another study, however, showed the opposite result. McDiarmid suggests that the problem with training in the classes he studied was reliance on the lecture method. He proposes that multicultural training will be more effective if students interact with each other rather than listening passively to presenters. Similarly, the Holmes Group (1990, p. 37) believes that most mandated courses on multiculturalism "lack coherence, intellectual rigor, and opportunities for follow-up and reflection and practice."

One researcher (Grant, 1991) notes that when teachers do ask for help in understanding students from other cultures, they generally assume some form of deficit in those students. He argues that it is most important that teachers understand themselves, their beliefs and biases, and the processes by which they have absorbed their own cultures.

Many teachers of science and mathematics are not even adequately prepared in the subject matter they teach. This often leads them to become authoritarian in their teaching style (Trumbull, 1990). According to Cummins (1986) and others, instruction that is characterized by dialogue and teacher facilitation, rather than lecture, drill, and other highly structured, teacher-controlled work, is more conducive to success for poor, minority, and female students. Given teachers who are inadequately prepared to teach, students with little or no out-of-school, informal instruction in science and mathematics — frequently true of minority and female students — begin to develop disadvantages in relation to other students who have more out-of-class experience.

Teachers' culture. A number of researchers (summarized by Davis, 1990) have identified characteristics of a teachers' culture that appears to be international: Teachers share a belief in individualism that leads them to cultivate the abilities of individual students. Teachers share the belief that they lack control over their own work, that initiatives and orders come from the top down; this belief is reinforced in the classroom, where the teacher becomes the "top" and students the "down." Teachers also seem to share a "practicality ethic," constructing recipes for transmitting knowledge out of their practical daily experience and common sense. Innovations threaten this recipe, and any change must be viewed by teachers as **practical,** useful in their daily work, **congruent** with the way they work, and **cost-effective** in terms of the effort involved in making the changes.

Curriculum. In 1989 the editors of *Scientific Literacy* found "existing scientific curricula socially, culturally, and cognitively outdated" (Hurd, 1989, p. 21). Curriculum must reflect the state of knowledge in the content area and be relevant to students.

Standardized tests drive curriculum. A recent study (Romberg, Zarrinia, & Williams, 1989) found that most teachers of eighth-grade mathematics made their teaching decisions based on the content of the standardized tests their districts administered to its students. This circumstance is common in other subjects and other grade levels as well, even though standardized tests are generally not aligned with student needs (Chambers, 1993). While the goals of mathematics, as articulated by the National Council of Teachers of Mathematics, are to include higher order thinking and a knowledge of topics other than arithmetic, researchers found that in six widely used standardized tests, 11 percent of the mathematics test items were conceptual and 89 percent were procedural. More than 70 percent of the questions dealt with arithmetic (Romberg & Wilson, 1992).

Approaching a fair curriculum. Current efforts at curriculum reform in mathematics and science generally focus instructional activities on topics and concerns that affect students' daily lives, and that develop higher-order thinking skills and problem-solving abilities. There are, however, few guidelines for assuring that curricula address the needs of all students.

Gretchen Wilbur, a curriculum researcher, has found six attributes of a gender-fair curriculum: It **affirms variation** by showing similarities and differences among and within groups; it is **inclusive,** allowing both males and females to find positive messages about themselves; it is **accurate** in the information and data it presents; it is **affirmative** in acknowledging and valuing individual and group worth; it is representative in **balancing perspectives;** and it is **integrated** in presenting the experiences, needs, and interests of various groups. Wilbur can name no major curriculum reform effort to date, including the NCTM standards and Project 2061, that fulfills all six of these criteria (AAUW, 1992).

While Wilbur's criteria have relevance to more than gender equity, the literature surveyed for this review reveals no explicit criteria for a culture-fair curriculum, though many proposals at least implicitly aim in that direction. Without defining "at-risk," the National Center for

Improving Science Education (1989) suggests criteria for addressing the needs of at-risk students. NCISE recommends that curriculum focus on students' **immediate environment** in order to relate to their daily lives; use biography and history to emphasize that science is **not the "exclusive province of white males"**; use **out-of-school resources** such as zoos, hospitals, and museums; use **cooperative learning** approaches, which can "significantly affect the achievement level and social skills of poor and minority children"; and employ instruction based on **experience and inquiry** that is "informed by the knowledge that children from various cultures view the natural world differently and approach learning accordingly" (p. 46).

Less is more — sometimes. Many researchers believe that the interests of all students will be best served by a curriculum that covers fewer topics in greater depth rather than many subjects superficially. Advocates of a less-is-more curriculum argue that it will give students time to test their ideas and link their learning to real-world experiences. "Less is more" is not the same as the spare "dumbing-down" curriculum that is often foisted on students labeled at-risk or forced onto the low track. Students engage in fewer topics but actually learn much more, because what they learn is clustered around "major organizing concepts" (NCISE, 1989, p. 10). Rural and low-track students, however, are often faced with curriculum that is stripped down yet offers no emphasis on concepts or developing understanding. This narrow, spare curriculum emphasizes disconnected facts, without the organizing principles that help students to "develop the mental structures that make the factual information memorable and useful" (NCISE, 1989, pp. 4-5).

Instructional approaches. The traditional lecture-dominated mode of teaching science and mathematics does not hold the attention of many students, especially not the attention of those who perceive themselves as "unscientific" or "unmathematical" in their intellectual makeup. Changing instructional methods for all students is an indirect approach to equity issues, but research suggests that such changes will benefit poor, minority, and female students while also engaging the traditional high achievers in science and mathematics.

The disembodied learning of mathematics and science. Elementary school children are seldom taught the content of science; rather they are drilled in discrete facts and "disembodied skills" (NCISE, 1989, p. 2). Students are given "textbook science" that offers them neither enough time nor experience to connect facts with the natural world or to make sense of the principles that underlie the facts. When these children enter secondary school they are expected to apply the facts and terms they were taught and to "memorize as many new terms as are required in foreign language classes" (NCISE, 1989, p. 2). The same process occurs in mathematics. This emphasis on memorization of isolated facts and formulas discourages learning.

Those involved in major reform initiatives in mathematics and science — for example, the National Science Teachers Association and the National Council of Teachers of Mathematics — advocate that teachers reduce the amount of material being covered, presenting key scientific and mathematical concepts in appropriate sequences within the context of the problems and needs of daily life. Such approaches can have fruitful results for students who have traditionally been denied success in science and mathematics. However, if concepts are not embedded within the curriculum in ways that allow them to be expanded and deepened rather than merely revisited, the idea of teaching concepts will degenerate into "a curriculum that goes around in circles" (McKnight et al., 1990, p. 99).

The NSTA also recommends that science and mathematics instruction occur *not* within tracked classrooms but within a heterogeneous classroom. Students of different ability levels then can "exchange ideas and learn from each other" (NSTA, 1992, p. 15). Similarly the NCTM (1992a) argues against tracking students.

Mainstream teaching or alternative methods? Teaching in most classrooms today more closely resembles that of 50 years ago than it does any instruction envisioned by educational reformers. The process is teacher centered. Curriculum is supposed to proceed in linear fashion from simple basics to advanced material in an environment controlled by the teacher; the instructional repertoire concentrates on "teacher explanation and independent seatwork" (U.S. Department of Education, 1993, p. 59).

According to the U.S. Department of Education (1993), children from low-income districts who were engaged in alternative teaching practices that emphasize meaning and understanding — for example, cooperative learning, use of manipulatives, peer coaching — usually had a greater grasp of advanced skills at the end of the school year than did their peers in traditional classrooms. When low-achieving and high-achieving students from low-income districts are both involved in such alternative instructional methods, each group strengthens its grasp of advanced skills.

Constructivist learning. Constructivism presumes learning to be an active process in which each student creates rather than receives knowledge. By the time they start school, students have already "constructed" ideas about mathematical and scientific principles. By analyzing students' preconceived ideas and helping students to build from those ideas in meaningful ways, teachers can promote learning. From this perspective, teachers become facilitators of experiential learning rather than transmitters of knowledge. Students are encouraged to explore new ideas in ways that have meaning and relevance for their own lives, to test their theories and beliefs and to compare their results with those of other students.

Constructivism requires a change in many teachers' assumptions about how children learn. "If one subscribes to a constructivist view of learning, then the goal is no longer one of developing pedagogical strategies to help students receive or acquire mathematical knowledge, but rather to structure, monitor, and adjust activities for students to engage in" (Koehler & Grouws, 1992, p. 119). The constructivist classroom is interactional and social rather than structured and hierarchical. The social nature of constructivist learning often engages students who before felt isolated by the abstract nature of the subjects.

Cooperative learning. Research consistently finds that students of all ability levels benefit from cooperative learning. Johnson and Johnson (1987) found that for all age levels, subject areas within mathematics, and tasks, cooperative learning promoted higher achievement than did competitive classes, in which students were to complete problems faster and more accurately than other students, or individualistic classes, in which students were expected to reach a preset criterion. Cooperative learning also may increase the group identity of children and help them to feel a part of the school. However, cooperative learning does not consist merely of placing students into small groups and assigning each student a role, such as recorder or materials manager; it requires carefully structured activities that cannot succeed without meaningful input from every student in the group.

Learning styles. Asa Hilliard (1989, p. 67) defines learning style as the "consistency in the behavior of a person or a group that tends to be habitual — the manifestation of a predisposition to approach things in a characteristic way." Some research on learning styles suggests that teaching may be more efficient if it takes into account the different ways in which individuals approach learning. While some researchers argue that poor and minority-group students tend to have learning styles that are different from those of other children, Hilliard cautions that learning styles are not innate but learned. He also notes that learning style does not of itself explain lack of academic achievement among minority students; other systemic factors are more important.

Opportunity to learn. The concept of "opportunity to learn" is used to ascertain what teachers actually present in the classroom, comparing that presentation to the "intended curriculum," or what students are expected to learn, and the "attained curriculum," or what students actually do learn. Generally opportunity to learn is measured by surveying classroom teachers. Some researchers (Stevens & Grymes, 1993) believe that opportunity to learn involves equity issues because students who have not had access — whether in their homes or in their schools — to the skills and subject matter considered average for their grade levels cannot obtain average scores on norm-referenced tests. Low grades on such tests are then interpreted to mean that the students did not work hard or were not capable of learning the subject matter. Frequently, however, their poor performances on standardized tests may be the result of classroom instruction.

Assessment. Assessment could have important positive effects on equity, but as presently practiced it appears to have a negative effect. Assessment in the United States mainly uses standardized tests to judge students, their teachers, the administration of their schools, and the school districts themselves — despite the fact that standardized tests generally encourage rote memorization and that scores on these tests have a weak relation to actual learning.

The testing culture of schools. The National Center for Fair and Open Testing (cited by Zessoules & Gardner, 1991) estimates that each child in the U.S. takes three standardized tests each school year. While standardized tests may not be intended for comparing one child with another, that is the common use between students and, too often, among teachers, parents, and schools. For children the stakes are high, and those who score low on standardized tests are often publicly labeled as failures (Jervis, 1991).

A major problem with standardized tests is that the questions asked on the tests are proprietary secrets. In most areas of intellectual endeavor, a public and available literature reports, discusses, and debates findings (Schwartz, 1991). However, standardized tests are prepared and administered with no oversight from the community that will be most affected by the results. In the Netherlands, by contrast, the national mathematics tests consist of many extended problems that must be worked out in context. Tests are published after they have been used, and they become part of materials available for school use.

Authentic assessment. Concern about standardized tests has led to the development of "authentic assessments," which are based on students' entire performances rather than on individual tasks. Most current attempts at authentic assessment consist of portfolios and performance-based tests that use science or mathematics centers or stations with manipulatives, measuring devices, or other instruments. At these stations students manipulate objects to explore concepts and to demonstrate their understandings.

Assessment is integrally linked with instructional methods, ideas about how children learn and what constitutes ability, and conceptions of valid knowledge (Singh, 1987). Changing assessment approaches, then, requires rebuilding the classroom culture. According to Zessoules and Gardner (1991), a culture supporting authentic assessment would nurture complex understanding, develop reflective habits of mind, document the evolution of student understanding, and use assessment as an opportunity for learning rather than merely as a test. The mechanical nature of assessment as a task that begins when learning stops would be ended by incorporating assessment into teaching and learning.

Many observers believe that individualized authentic assessments will especially benefit female students and those from minority group or low socioeconomic backgrounds, but at present this belief has not been rigorously tested. One study has found that low-income kindergarten children performed addition and subtraction problems better on nonverbal formats than they did on any of three verbal formats (Jordan, Huttenlocher, & Levine, 1992). Interactive teaching, attention to cultural diversity, and an emphasis on conceptual and contextual thinking seem to be more amenable to authentic assessments than with traditional forms (NCTM, 1991).

Unless alternative assessments include a large number of tasks they may be poor indicators of student achievement. In deciding what a student knows or can do, "determining a student's abilities in a variety of situations is more important than obtaining a single score on a highly reliable test" (Webb, 1992, p. 668).

Different assessments for different students. Traditional assessments administered to groups of children are unlikely to identify gifted children who are poor readers or underachievers or students whose first language is not English. The ideal in such situations, according to Hooker (1993), is individual tests administered by people with experience with learning disabilities, bilingual children, underachievement, or reading problems. In the end, no single assessment is adequate for identifying "the multifaceted nature of giftedness" (p. 54).

The use of alternative assessments will particularly benefit students whose facility in English is limited, those who speak or write nonstandard English, and special education students. According to the authors of *Assessment Alternatives in Mathematics* (1989), students with limited English proficiency should be provided with translators; special education students should be given the opportunity to display their abilities through portfolios, performance tasks, and other assessments.

In addition to presenting tests in children's native language, alternative methods of presenting questions and assessment procedures include using manipulatives, videotaping, computer-based presentations, and teacher-taught introductions to performance tasks. Students can present responses by constructing objects, creating patterns on computer screens, or explaining solutions orally rather than in writing.

Alternative assessments in themselves cannot be treated as answers to equity problems. Unless such assessments are part of larger changes in schooling, they may actually be detrimental.

Culture inside and out of school. Many observers of education believe that problems in achieving equity are embodied in the very culture of schools and in the cultures of the larger society and the various groups within it. Attitudes toward mathematics and science — and those who pursue those fields — are part of our national culture. Race, ethnicity, gender, and class are categories laden with cultural beliefs and biases, often unconscious. To consider equity, then, is to wade into complex cultural waters.

Caste stratification and cultural inversion. John Ogbu (1978) has proposed that the poor school performance of many African-American children results from the American caste or racial stratification system. He defines a group as a *caste* if it is seen as "inherently inferior" by the majority and is stigmatized and excluded. Training and ability, he notes, will have no bearing on the roles society assigns to members of such a group. Ogbu holds that many African-American students have not succeeded in school because they see that, historically, effort expended in schoolwork has not benefited African Americans. An example bearing out his argument is the fact that, in the early 1980s, high school dropouts from wealthy white New York neighborhoods were more likely to be employed than were high school graduates from poor black neighborhoods (Tobier, 1984).

In a 1990 update of his views Ogbu added that involuntary minorities — groups whose ancestors did not voluntarily migrate to what is now the U.S. but who were either already here or were brought here against their wills — often practice "cultural inversion." In this process, members of the minority cultures, in order to survive as a cultural group, reject symbols, events, and behaviors that are characteristic of the dominant culture. Such survival techniques, developed over long periods, may be difficult to change, even if members of the majority culture begin to change their beliefs and behaviors. His ideas are supported by Fordham (1993), who did an anthropological field study in a Washington, D.C. high school. She identified a force she calls "fictive kinship" among African-American students, which she says symbolizes peoplehood in opposition to the prevailing white society. Fictive kinship, she holds, leads students instead to see their own chances of success as linked with the chances of their peers and their community. Fordham (quoted by Schmidt, 1993, p. 14) says of this peer pressure, "I never believed it would be so pervasive and so pronounced, and so academically stifling."

Students' competing worlds. Phelan, Davidson, and Hanh (1991) have developed a generic model of the interrelationships among a student's family, peer, and school worlds. These worlds are congruent for some students; in these situations all transitions between these worlds will be smooth. For other students, however, these worlds are not congruent. For some students the worlds are totally impenetrable and no crossings can be made. The research of Foster (reported by Mehan, 1992) has found that classroom participation among African-American students increases when teachers use language and participation structures that are congruent with those of the students' homes.

While mainstream education is teacher-centered and emphasizes continual evaluation of right and wrong answers from the student, socialization in most Native American and Hispanic cultures emphasizes cooperation and peer relationships. Native American children often will not answer a question until all other children in the class are ready to answer, are uncomfortable in situations that require them to interact with adults rather than other children, and may "have great difficulty with direct questioning techniques employed in most school situations" (Charbonneau & John-Steiner, 1988, p. 92). These cultural preferences may carry over into other situations, such as teacher-parent conferences, in which direct questions seldom reveal the actual thinking of the parents.

The U.S. Department of Education (1991, p. 16) has found that "schools that adjust their curriculum to accommodate the variety of cultures served are more successful than schools that do not." Respect does not merely involve incorporating famous names and ethnic holidays into the classroom, but creating a match between the meanings, processes, and behaviors encouraged by schools and those valued within the student's culture. "A widening of the range of acceptable meanings is a signal by the school that it accepts cultural diversity as a real, normal, and permanent feature of society" (González, 1993, p. 259). González believes that such changes cannot be made through materials or the adoption of new district policies, but only through classroom activity: "The change that is needed is chiefly in the professional behavior of school personnel" (p. 260).

The importance of language. Language may be another key, for "the language providing the greatest potential for intellectual development is the language reinforced in both the school and the home" (U.S. Department of Education, 1991, p. 16). Much research indicates that performance in mathematics improves when students are instructed in their first language. When Hispanics who were Spanish dominant received mathematics instruction in Spanish, their performance equaled that of non-Hispanics. Student errors increased, however, when the language of performance and the dominant language were not the same (Cocking & Chipman, 1988, p. 35).

Nonremedial culture-based teaching. T.L. McCarthy and colleagues (1991, p. 43) have warned that research into the differences among ethnic learning styles and cultural preferences should not be used to justify "remedial, nonacademic and nonchallenging curricula" for students from minority groups. Teachers who have been trained to expect that certain types of children will be passive or will not ask questions may never give those children an opportunity to engage in "active, open-ended discussion" (p. 54). If teachers have only a shallow understanding of their students' cultures and then use that partial understanding to form or reinforce stereotyped ideas about learning styles, their simplifications will result in a pedagogy that debilitates children.

Female students and cultural expectations. Social conditioning and stereotypes about both science and women help to keep young women away from mathematics and science. Mexican-American parents studied by MacCorquodale (1988) tended to stress the importance of education for all their children, but also were more likely than Anglo parents to discourage girls from pursuing nontraditional careers. A 1987 study by Campbell and Connolly indicated that parents supported European-American girls in avoiding mathematics and science; Asian-American parents, however, did not practice this "over-protective" behavior. Bernice Sandler has found that in the general U.S. culture scientific or mathematical success by men is attributed to talent while women's success is attributed to luck or hard work (both studies cited in *Dwight D. Eisenhower Mathematics and Science Education Newsletter,* 1993).

Religion and the scientific culture. Phelan, Davidson, and Hanh (1991, p. 232) point out that for many students the "family world may be dominated by an all-encompassing religious doctrine in which values and beliefs are often contrary to those found in school and peer worlds." In the U.S. official conflict between students' religious worlds and school worlds often focuses on the teaching of evolution in the public schools. The use of science to obtain control of the physical environment is often threatening to traditional Native American tribal beliefs; among Native Americans who have totem animals, dissection of that animal or handling of its bones also may be unacceptable (Caduto & Bruchac, 1988). Other religious groups will have still different philosophies regarding the natural world, and science teachers must deal with these views in the classroom. If teachers "teach the truth of their disciplines," can they also "respect the beliefs and values of students and their parents"? (Garcia, 1991, p. 57).

The creation of at-risk students. The label of "at-risk student" is applied to a student who is "at risk" of not doing well or staying in school because of various social, economic, and psychological factors. Equity concerns necessarily involve this concept since many students who do not do well in school and who come from poor or ethnic minority backgrounds end up with this label.

The concept *at risk* is borrowed from epidemiology, the study of patterns of disease distribution and the factors affecting those patterns. The job of the epidemiologist is to identify people in the greatest risk categories. Two limitations must be observed in using the term in medicine: First, when a population is labeled, the condition for which they are at risk must always be identified. Second, being at risk is a relative concept, since everyone may be at risk for a condition, such as heart disease, to a greater or lesser degree. However, when the concept is used in education these two limitations are often ignored. When the model is moved into education, identification of students based on social characteristics becomes not only inexact but controversial (Richardson et al., 1989).

Social constructivist model of at risk. Richardson and her colleagues (1989) have devised an alternative model of at-risk factors based on social constructivist thought rather than medicine. In this interactive model, the student who is at risk, the reasons for this labeling, and the responses of school personnel are all seen as constructed within the culture of the classroom and the school. In this model the focus is not on the child alone, but on interaction within a series of contexts.

Teachers' lack of understanding about the way their own perceptions and behaviors shape the identification process can lead them to assign all causes of at-risk behavior to students' home life and family members. Teachers work from their own ideas of what a "good" family is — an ideal that has much in common with their construction of the ideal student. While such approaches may result in inaccurate labeling of children as at risk, or of homes as deleterious to their children's learning abilities, they also may deprive other students of needed attention. Children whose behaviors fit within the teacher's classroom expectations may not be recognized as being at risk and may never receive the help they need. For example, a 1986 dissertation (Goldenberg, cited in Richardson et al., 1989) found that Hispanic girls generally are not diagnosed as having learning problems because they are skilled at covering up such problems.

Instructional strategies for at-risk student. Richardson and her colleagues (1989) found that when students fall behind in their studies, remediation is more successful if it accelerates the pace of instruction rather than slows it down. Although this idea appears to be counter-intuitive, slowing down of instruction generally breaks the material into pieces that are so small they become boring and meaningless. As instruction is slowed, the gap between the student and the rest of the class becomes wider, expectations are reduced even further, and mechanics are emphasized over substance. Merely accelerating the traditional curriculum, however, is not the solution; presenting material in new, challenging, and meaningful contexts is essential. Pull-out programs, which are often used as a remediation strategy, often create more problems than they solve. The most insidious problem of pull-out programs is that they relieve the classroom teacher and the school from making systemic changes that can benefit all students (Richardson et al., 1989).

PART 3:

Strategies for Achieving Equity

In schools, university research projects, and public arenas across the country various strategies have been tried in an attempt to equalize opportunities for educational success for all students. Some strategies have been tested using rigorous research methods; others have been recounted in impressionistic reports of what some educators perceive to be working in the classroom. Strategies targeted to specific populations and those aimed at improving instruction for all students have been tried.

Strategies and programs specifically targeted to female students. Some data suggest that female students may learn science and mathematics best in an all-female environment. Emphasis on hands-on work and cooperative learning also seems to attract more female students to science; several successful programs for young women use mentoring strategies.

Hands-on classroom work. In a study of eight fourth-grade classrooms in Boston, researchers found that boys and girls appear to benefit from hands-on methods of science instruction, and that girls perform as well as boys when classroom instruction emphasizes active learning (Dalton et al., 1993). The practice of using same-sex pairs also may have improved performance; girls who worked in same-sex pairs were more active in class discussion than they had been previously.

Young women from the fourth through tenth grade are targeted by the EQUALS Teacher Education Program, developed by the Lawrence Hall of Science. Female students are introduced to the language and tools of science, mathematics, and technology. Students then design several construction projects. Where the EQUALS program has been in effect for two or more years, the interest of young women in advanced mathematics classes has increased slowly but steadily (Lawrence Hall of Science, 1982).

The University of Michigan sponsors two hands-on summer programs to interest precollege girls in science. In Summerscience for Girls, eighth-graders come to campus for two weeks, attend seminars, and participate in projects in specific disciplines. In Science for Life, high school girls intern in the laboratories of women scientists for six weeks; interns work on their own research projects and participate in a symposium at the end of the program (Travis, 1993). A similar program is Careers in Engineering for Women, held at The University of Texas at Austin. The program brings seventh and eighth graders to campus for two one-week summer sessions; they complete laboratory activities that are designed to develop mathematics, science, observational, problem-solving, and critical thinking skills (TEA, 1993).

Extracurricular activities. Many programs aimed at female students use extracurricular activities to supplement traditional classroom instruction. These activities tend to emphasize learning in a same-sex environment. Several programs are targeted to the junior high years, since many observers believe this to be a crucial period when young women begin to feel pressured to hide their intelligence and allow boys to better them in the classroom (Travis, 1993). Information on extracurricular programs is anecdotal.

A fourth-grade girls' science club in Boston emphasized hands-on work during camping trips, field trips, and other activities. The club competed in the seventh annual battle of LEGO robots sponsored by MIT; the girls placed well in a field that included college students and teams from high-technology firms in the area. Traditional extracurricular organizations, such as Girls Incorporated and the Girl Scouts, also have begun programs that encourage science activities among their members. Girls Incorporated offers Operation SMART, a hands-on and mentoring project for elementary and junior high girls; a survey of the girls in one urban club found that their occupational goals had changed from secretary, nurse, and teacher to scientist and engineer (Travis, 1993). The Girl Scouts offer Girls and Science, another hands-on and mentoring project developed by the American Association for the Advancement of Science. In participating troops, the number of science-related merit badges the girls earned increased by 57 percent.

Strategies targeted to students from minority groups. Experience suggests that role models and mentors for African Americans, Hispanics, and Native Americans help to counteract the low expectations of authority figures in the schools. Cooperative learning in small study groups, emphasis on challenging work, good study habits, culturally relevant materials, peer support groups, and involvement with the student's family and community are features of several programs. Most of the programs emphasize building support for students with academic interests; these programs use study groups, clubs, other peer-age groups, and mentoring to foster interest and ability in mathematics and science. Several programs, rather than focusing on innovative teaching methods, emphasize preparing students to cope with existing structures, such as standardized tests, that might filter them out from a college education. Information on classroom results is sketchy and often involves students' improvement on standardized tests.

Mentoring. A nationally recognized program, the Incubator Scientist Program, identifies promising young people from minority groups in St. Louis schools. Students attend a five-week summer academy, then choose a research topic and are assigned a mentor who works in area industries. In the second year, students participate in another workshop, continue work on their research projects, and become mentors to the next crop of ISP students. Out of the program's first group of 11 students, 10 attended college (Allen, 1993).

The Texas Alliance for Minorities in Engineering also offers summer enrichment and tutoring programs and assigns mentors from industry to work with each student. Mentors tutor students, advise them about career choices, and help them find summer employment. Between 1976, when the program began, and 1991, minority enrollment in engineering programs in Texas increased by 55 percent (TAME, n.d.).

Group studying. The Mathematics, Engineering, Science Achievement program, which operates in New Mexico and California, emphasizes study groups and academic advising. It offers enrichment programs, career counseling, scholarships, and family involvement programs for secondary school students and workshops, orientation, summer jobs and other aids for college-legel students (Gibbons, 1992b).

Academic enrichment. The Texas Prefreshman Engineering Program identifies high-achieving middle and high school students from sixth through eleventh grade. These students attend eight-week mathematics-based academic enrichment programs, held in the summer on college campuses. Students may participate for up to three years. While the program is open to any high-achieving student, female students and students from minority groups are specially targeted. Of the former TexPREP participants who responded to a 1992 survey, 74 percent of the science and engineering majors were from minority groups (TexPREP, 1993; Berriozabal, 1992).

Test preparation. Several programs try to ensure that average students from minority groups stay in school, take more science and mathematics courses, and eventually obtain a postsecondary education. Venture in Education began with high school students in Brooklyn, Harlem, and rural Alabama and now includes 39 schools across the country. VIE sets specific high school course requirements for participating students, who also attend summer academic programs and SAT preparation classes. Minority VIE graduates tend to enroll and major in science disciplines to a greater extent than do the general population of minority students (Gibbons, 1992b).

Partnership to Improve Minority Education, administered by Arizona State University, has developed strategies that reached 22 high schools and 60 elementary and middle schools in 1992. Algebridge, a PRIME program, teaches junior high students to achieve well on traditional assessments. In one community, the average mathematics scores on the eighth-grade Iowa Test of Basic Skills moved from the 29th to the 48th percentile after one year of the program. PRIME also offers a 25-hour course in test-taking skills to familiarize students with college entrance examinations and test-taking strategies; it trains teachers in teaching advanced placement courses, and offers enriched science and mathematics activities to schools.

Teacher development. Another approach to nurturing educational success for minority students is to focus on training their teachers. A Texas program, the Minority Mathematics and Science Education Cooperative, offers elementary school teachers training to increase their conceptual knowledge of mathematics, earth or life science, and physical science; their teaching practices; and their knowledge of their students' cultures. MMSEC uses an annual institute, with nine-month sessions based in the individual schools, and annual summer courses to provide teachers with in-depth training and follow-up. The program, which targets schools in which a majority of students come from minority groups and low-income families, uses a training-of-trainers approach and works with schools over a four-year period (Texas Higher Education Coordinating Board, n.d.).

Strategies targeted to specific language groups. Students with limited English proficiency appear to benefit from programs that use collaborative learning and hands-on activities. Improvement in science and mathematics learning can have positive effects on other domains as well.

The Program for Complex Instruction at Stanford University has developed science activities for younger children, primarily from low-income, Spanish-speaking families. Working in small groups, the children perform science tasks related to everyday life. Researchers found that students improved not only in their scientific and mathematical abilities but also in their ability to read and speak English (Gibbons, 1992a). The program has now published a curriculum and added material for middle-school grades (Larson, 1993-94). Language is also an important part of the approach to science and mathematics education in Kids Investigating and Discovering Science, a program based in Irvine, California (Gibbons, 1992a).

Staff at the Hawthorne School have devised mathematics lessons that also focus on the language patterns of speakers of Black English Vernacular. The object of the lessons is to force students to push the limits of their own language and then to use new language tools to open new areas of thought (Orr, 1989, p. 211).

Maker and her colleagues at the University of Arizona have developed a series of problem-solving tasks to identify gifted students whose potential may be hidden by their limited English proficiency. Others also have developed similar tests. Raven's Progressive Matrices is a nonverbal test that calls on children to solve problems using abstract figures and designs. A test developed by Edward DeAvila uses cartoon-like illustrations; it is used as a preliminary screening device for young children (*Education Week*, 26 May 1993).

Strategies targeted to rural students. Few programs are particularly aimed at children in rural schools, though rural schools can be among the most neglected and poor schools in the country. Most projects focus on teacher training.

In Texas the Rural Elementary Science Improvement Project emphasizes workshops for rural teachers, offering two-week summer programs and day-long workshops throughout the school year (Texas Governor's Office, 1991). In Oklahoma a program jointly funded by the University of Tulsa, the National Science Foundation, and cooperating school districts sponsors workshops to strengthen rural teachers' understanding of basic physics and chemistry; the program introduces them to hands-on methods to increase their confidence and enjoyment of science (SCIMAST, 1993). Since 1990 the Northwest Regional Educational Laboratory has administered the Science and Mathematics Academy for Rural Teachers, a two-week regional academy (*Dwight D. Eisenhower Mathematics and Science Education Newsletter*, 1993).

The Indiana-based Project SPRING looks for gifted students among Appalachian children in the southern part of the state. Students in the program complete projects, such as designing a dwelling for the night, that tap different kinds of intelligences and use rural knowledge (*Education Daily*, 13 May 1993).

Remote learning technologies offer some rural schools access to a more challenging curriculum. Since 1987, Oklahoma State University has sponsored a program that uses live instruction via satellite to bring advanced placement chemistry classes to small rural schools in the state. The program attempts to preserve as many of the benefits of live teaching as possible; students can question the video instructor and respond to instructor questions (SCIMAST, 1993).

Reaching all children with reform in mathematics and science education. Children come to school with an informal, home-based understanding of the natural world and of numbers. Once in school they must try to connect this informal learning with the formal contexts of the classroom. Ginsburg and Russell (1981) have pointed out that all children enter school with backgrounds that enable them to cope with these systems; it is traditional schooling that changes this disposition. Schools must help students to make connections between their informal learning and the classroom; many observers believe that this can best be accomplished through programs that affect all children, programs that go beyond textbooks to emphasize experiential learning that draws from the communities in which children live (Charbonneau & John-Steiner, 1988).

Developers of a number of widely publicized programs believe that transforming science and mathematics teaching for all students is the best way to improve the academic performance of traditionally under-represented groups. The drive to establish standards in mathematics and science, national programs such as Project 2061, Scope, Sequence, and Coordination, and Equity 2000, and state and regional efforts at "systemic" reforms are all targeted to entire student populations rather than to specific groups. All are relatively new and have little to report as yet regarding effects on student achievement.

The standards movement. In 1989 the National Council of Teachers of Mathematics released the first major document in the recent movement for "standards" in education. The NCTM standards emphasize heterogeneous classrooms, active learning, collaborative student work, and an in-depth focus on major topics and concepts. With extensive input from teachers across the country, NCTM has developed a detailed series of publications outlining standards for student knowledge and skills, teacher behaviors, and assessment, as well as supporting documents describing learning sequences and activities that address the standards (NCTM, 1989; 1992; 1992a). The National Research Council is working to produce a similar set of standards in science (NCESA, 1993a).

Some observers express concern about the standards movement, from funding issues to the mechanics of their implementation to equity issues (Brown & Borko, 1992; Apple, 1992).

National reform projects. Project 2061, sponsored by the American Association for the Advancement of Science, and Scope, Sequence and Coordination (SS&C), sponsored by the National Science Teachers Association, are two major national projects that share many similarities. Both propose alternatives to the traditional structure and content of science courses, and both advocate depth of coverage rather than the teaching of isolated science facts. Each program has sites scattered throughout the country that are developing and testing approaches. Equity 2000, sponsored by the College Board in six school districts across the country, is a program aimed at increasing enrollment in algebra classes. The program restructures mathematics programs to eliminate tracking and works to change the attitudes of teachers and counselors regarding students' capacity to learn algebra. The work of the National Center for Research in Mathematical Sciences Education focuses on general restructuring of mathematics.

Regional, state, and local efforts. Several states have developed models of systemic reform. South Carolina, for example, has adopted goals and supporting mechanisms focused on gains in graduation rates, standardized test scores, and college entrance rates; increases in academic courses taken; and greater teacher satisfaction, among others (Clune, 1991). Roots and Wings is a state-level school restructuring program in Maryland, designed with participation by researchers from Johns Hopkins University. An integrated, thematic approach to science education, the program makes each school a family development center that provides federal, state and local services to families in need as well as providing new educational approaches for students (*Education Week*, 4 August 1993).

The National Science Foundation is funding Statewide Systemic Initiatives in 25 states, with the idea that mathematics and science education can be improved for all children only if isolated reform efforts are replaced by reforms that affect the entire educational system (SRI, 1993). The NSF has left a great deal of latitude for states in implementing their reforms, and different states have followed divergent paths.

Local school districts and individual schools throughout the country also are developing their own initiatives to improve mathematics and science education. Their focus includes assessment; creation of magnet schools; changes in instructional approaches such as interactive teaching, cognitively guided instruction, and a focus on cultural contexts; and uses of technology.

Efforts to achieve equity in school financing. All states — except Hawaii, where the state fully funds all education — finance their public education systems through some combination of state and local tax revenues (Walker & Kirby, 1988). In recent decades this finance structure has been challenged in the courts and legislatures of several states. For example, Texas has been dealing with the equity of school financing for more than 20 years; consolidation has emerged as the best solution for both courts and legislature, although it has many problems, mainly political, too. Michigan has taken the more radical step of banning property taxes as a method for funding public schools beginning in January 1994. Some U.S. senators have suggested creating a federal fund to help states equalize the imbalance between rich and poor districts; other public figures have suggested a federal value-added tax to aid education.

Many states are turning to lotteries and various forms of legalized gambling to solve financial problems. As supports for education, however, these carry some grave problems; in practice, lottery money does not supplement regular school funding but supplants it.

Court cases since the 1960s have established a body of legal principles regarding educational finance equity. Two standards of equity have emerged. **Expenditure equity** requires that districts spend similar amounts on each pupil; **fiscal neutrality** requires district expenditures to be independent of district wealth.

PART 4:

Conclusions

To achieve equity in science and mathematics education, the structure of U.S. schooling will have to be transformed. Such a transformation will involve more than changes in classroom configurations or funding distribution; it will have to involve "a structural change in the ways in which. . . voices are incorporated" into the classroom (Wallace, 1994, p. 186). It will have to involve valuing differences while inviting all to share in the whole (McLaren, 1994). This whole, however, will not be the "harmonious whole" of the melting pot, but rather a "difficult whole" that accommodates varying and sometimes contradictory realities within its totality (Murphy, 1991, p. 126). Equity can be achieved only if all voices are valued and subjected to the same processes of critique and investigation.

If instruction is to be transformed, science and mathematics teachers will have to move from their positions in the center of the classroom to allow children to investigate with their own tools. Students and teacher will together critique their ideas and methods and arrive at findings. Hands-on, collaborative, and constructivist methods will help children to use their natural interests in the world around them to create new understandings of mathematics and science. To achieve equity in the classroom, teachers will have to be self-aware — to acknowledge their conceptions of students and cultures and to understand the shape culture has given to their own learning. In the final analysis, the true transformation of education will arise from classroom respect for individuals and the learning that is being offered.

Educators will need to take care not to make new approaches as unthinking and stereotypical as traditional ones. If, for example, students spend their time making Jell-O molds of dinosaurs and everyone calls the result "hands-on science," no improvement over the lecture system will have been realized. If teachers deal with children in stereotypical ways in the name of cultural diversity, inequities will continue.

Inequities in schools are a reflection of inequities in the larger society. If attempts at achieving equity in science and mathematics education are not part of strategies "to eradicate the uneven impact of privilege and oppression" in education and in society at large, they cannot fully succeed (Hilliard, 1988, p. 42). For Hilliard, "it is politics, not pedagogy, that prevents school people from doing their best with all pupils" (pp. 42-43).

Schools cannot solve the problems of society on their own, but schools are an integral part of any answer that will work. And no matter what society at large does, schools must critically rethink and transform their purpose within that society.

Equity in the Reform of Mathematics and Science Education

Table of Contents

INTRODUCTION

This paper is a synthesis of the current literature on equity in precollegiate education. It attempts to pose persistent questions and present possible answers. What is equity? Who is affected by equity concerns? What issues must be addressed? What works to advance equity? What does not work? What has not been considered?

The purpose of this overview is to provide a knowledge base for policy and planning. Today we recognize that educational reform must be *systemic*, that is, must permeate every level and aspect of education. Equity also must be systemic; it must be a central concern of educational reform. No educational system can thrive if students are ignored or disenfranchised, if it cannot address the strengths and needs of all students.

The intended audience of this paper is those who are engaged in conceptualizing educational reform—primarily policymakers, administrators, program planners, teacher educators, staff developers, and staff of major reform projects. A companion guide—*An Action Guide to Equity in Mathematics and Science Education*—designed for school-based audiences (teachers, curriculum supervisors, and principals) will be available in the winter of 1994–1995.

As a synthesis of the literature, this paper is limited by what exists. It is not meant to be an original work, but a guide through the productions of others. While its focus is on mathematics and science, this paper also reviews the wider educational literature addressing equity concerns. The persistence of inequity in education is an issue wider than mathematics and science; for that matter, it is an issue that reaches beyond education. This paper is meant to suggest some lines for future thinking and action.

This document was developed by the Southwest Consortium for the Improvement of Mathematics and Science Teaching (SCIMAST), whose purpose is to further education reform efforts in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas. More information about the consortium and its counterparts in other regions can be found in the appendix. The consortium is operated by the Southwest Educational Development Laboratory, which has provided educational services to its region since 1966.

Many people have contributed to the production of this paper. It has been read and critiqued by SCIMAST staff members and by outside readers. None of these people are responsible for errors. They all contributed important and fruitful ideas and lines of investigation.

Equity in the Reform of Mathematics and Science Education

PART 1:

What is Equity? Why is It Important to Everyone?

Can the nation's schools achieve equity in science and mathematics education at the same time that they try to achieve excellence in those areas? Can educational reform succeed if it does not recognize the divergent needs of the nation's students and schools?

More than a decade ago the National Commission on Excellence in Education called for reform of public education and singled out science and mathematics education as areas that needed special attention. At the same time the commission pointed out, in *A Nation at Risk*, that students must have a "fair chance" to acquire "the tools for developing their individual powers of mind and spirit to the utmost" (National Commission on Excellence in Education, 1983, p. 4). Without such "tools" students will not be able to meet future personal and work demands. They "will be effectively disenfranchised, not simply from the material rewards that accompany competent performance, but also from the chance to participate fully in our national life" (p. 7).

Can U.S. education meet the two goals of improving science and mathematics education and ensuring that the tools of knowledge are equitably distributed?

Mary Metz, of the National Center for Research in Effective Secondary Schools, holds that the current reform movement, spurred by the release of *A Nation at Risk*, is flawed by a failure to consider differences among schools and the students who attend them: "The assumption that a school is a school and a student is a student, that all are fundamentally alike, has a long history in American educational discourse. It reflects our national image of public schools as all essentially the same, a national ritual experience, which provides us a common background" (Metz, 1988, p. 20). If this common background is assumed, the divergent needs of individual schools and students can be ignored. This paper supports Metz's argument that reform will be unsuccessful unless it considers equity in the distribution of resources and opportunities within the great diversity of both schools and students in the United States.

Equity, however, is a nebulous concept. What is the difference between equity and fairness, equity and justice? Is equity the same as equality? Is the goal of equity to see that each child is treated in exactly the same way as every other child or is it to ensure that each child is free to develop fully in his or her own diversity? Should equity be a concept that is used to ensure that the needs of the labor market are always met or should it have more individualistic and personal goals? What are the best strategies for dealing with inequities?

CHAPTER 1.1 Definitions of Equity

People mean different things by the word equity. It is used to mean equal access of all children to instruction, inclusion of all in the classroom, capacity building, diversity, or the offering of special services. Some, however, fear equity in any form.

Equity was originally a legal concept. In English law, courts of equity rendered decisions when it was perceived that strict adherence to the written law would result in injustice. *Equity* is less rigid than either *justice*, which follows the letter of the law, or *equality*, which, as a mathematical term, implies absolute balance with no considerations of fairness (*Webster's Dictionary of Synonyms*, 1942). In education equity involves, among other ideas, considering special needs of individual students in the learning environment—whether those needs require changing the construction of a classroom door to accommodate a wheelchair or refashioning instruction to ensure that each student can reach an understanding of the activities.

Who is Included?

Discussions of equity often focus on "underrepresented groups," but exactly who is in these groups is often a matter of some debate.

Discussions of equity in science and mathematics education tend to focus on women, African Americans, Hispanics, speakers of nonstandard English, and Native Americans. The National Council of Teachers of Mathematics (NCTM) has a goal of including "underrepresented groups" in "all aspects of mathematics education." NCTM defines an *underrepresented group* as "composed of students who do not take advanced mathematics courses and fail to enter mathematics-related vocations and careers in proportion to their representation in the population. The groups include females, blacks, language-minority students and Native Americans" (NCTM, 1992, p. 16).

Others have included additional groups in concerns about equity: students in rural schools, all those in lower socio-economic groups, and students with different physical and mental abilities, including gifted children. In *The Condition of Education 1993*, the National Center for Education Statistics (NCES) presents data confirming that regardless of ethnic background children from low-income families and students with parents who are poorly educated are caught in a cycle of low achievement (*Education Daily*, 30 July 1993). Ricardo L. Garcia (1991, p. vii) broadens the list of the underrepresented to include those affected by "gender, handicapping conditions, religion, social class, race, and ethnicity." For Herbert Ginsburg (1988, p. xii) equity involves many "problems slighted in cognitive research—problems of bilingualism, culture, class, gender, affect, learning styles, motivation, the availability of sound educational opportunities, teacher competence, the implemented curriculum (as contrasted to the intended curriculum)."

Several operational definitions of equity can be distilled from the literature. Among these are access, inclusion, enabling, diversity, and special treatment. Some believe that equity—no matter how it is defined—is a threat to, rather than a hope for, American education.

Equity as Access

Some define equity as nothing more than physical access to learning. Refraining from stopping children from acquiring learning is equity to those who accept this definition.

Either explicitly or implicitly, equity can mean equal access and nothing more. This traditional, common view of equity implies giving each child equal opportunity to participate in and learn from the class. As long as no one is denied the right to learn, equity, according to this usage, has been achieved. Achieving equity by this standard merely requires not interfering to block a student's progress. This view of equity requires no positive work on the part of teachers, school, or community. Equity is reached, in this definition, if a student is guaranteed "*individual choice* under the conditions of a 'free market'" (Apple, 1989, p. 35). Maxine Greene (1978, p. 65), of Teachers College, Columbia University, has called this view the "meritocratic paradigm." According to this view, only an unmotivated or inept child will be unable to move up the ladder of school success. In any case, the school cannot be blamed because the child has chosen "his or her own submergence or passivity."

Usually this meritocratic approach means that the school or the teacher sets the classroom terms and uses whatever structure, focus, pace, and instructional approaches they prefer. The class, as determined by the teacher or school, may or may not be appropriate or relevant for the entire classroom of children. Some children may be alienated and others may find that their abilities are not fully used or acknowledged. While no one is actively denying any student the right to enter into the class work, some are not benefiting from it as fully as they could.

Equity as Inclusion

Inclusion is beyond physical access and involves acknowledging the knowledge, needs, and abilities of all students.

Monty Neil of the National Center for Fair and Open Testing (1992), defines *equity* as "a process of inclusion." Inclusion, according to Neil, means more than opening the door to a school or classroom so that all may enter. It involves transforming both content and instructional approaches to address every student's interests and needs. Rather than seeing that students do well on "someone else's terms," educators must improve the "fit between instruction and students' learning"(Winfield & Manning, 1992, p. 184).

Equity as inclusion has several implications. Under this concept, for instance, the definition of excellence may change as individual student needs, strengths, and interests are identified. Issues of race, class, gender, language, and national origin will have to be addressed in all aspects of the school. In Neil's approach multiculturalism will be active. It will actively oppose stereotypes and other activities and ideas that lead to exclusion and will incorporate differing perspectives as integral parts of the school environment. In this context *inclusion* must refer to its more rigorous meaning of addressing, recognizing, and taking in all existing parts of the whole, rather than its more recent watered-down meaning of adding new parts that are perceived as standing outside the whole. Inclusion means acknowledging the abilities, gifts, and contributions of all components as necessary parts of the whole. It means acknowledging that students who have not been well served by the educational system are not "outsiders" who have to be "let in." Rather they are already rightful parts of the existing whole. Their needs, strengths, and interests are essential to the well-being of the whole educational enterprise (West, 1993b).

Complex problems arise from inclusive schooling and assessment. The education of teachers and administrators, parental understanding of the functions of schools, the school's ability to allow students to learn as they build their own identities, and the need to change parents' and educators' ideas that conform to existing inequitable standards are influential factors that are increasingly important in U. S. education. Assessment will have to assist and document individual learning and maintain the accountability of systems while allowing for their improvement (Neil, 1992).

The National Committee on Science Education Standards and Assessment also defines *equity* as inclusion in its goal of "science for all" and adds that "various styles of learning and differing sources of motivation" must also be part of equity considerations (National Research Council, 1993, p. 1). The committee's definition of inclusion, therefore, explicitly addresses students who come to education with motivations, interests, and understandings about science and mathematics that seem outside a supposed mainstream or norm of learning.

Equity as Capacity Building

To others equity means supplying all students with the appropriate tools for dealing with the post-graduation world.

For Thomas W. Payzant and Dennie Palmer Wolf equity "enables" students rather than remediating them. Students in an equitable school system can take mathematics courses that consist of "more than blind calculation and formula juggling" (Payzant & Wolf, 1993, p. 43). Each student is educated to the highest level of competence he or she desires or needs to exist in the world after high school graduation—whether that world is college or immediate employment. "We can no longer be content solely with the simple arithmetic of inputs—racially mixed schools, racially diverse teachers, classes of equal size, and bilingual opportunities for learning" (p. 42).

Payzant implemented his vision as superintendent of the San Diego schools. Lower-level mathematics and science electives were eliminated. General, consumer, and business mathematics courses were replaced by a prealgebra-algebra sequence for all students. Payzant and Wolf see equity as a matter of supplying all students with the appropriate "additional tools" needed to cope with the postgraduation world. Obviously, if such a plan is to succeed in high school some earlier program will have to ensure that elementary students possess the skills and background to help them succeed in these subjects.

Equity as Diversity or Multiculturalism

Equity as diversity or multiculturalism is not the addition of materials or ideas from underrepresented cultures; rather it involves the integrated use of content and approaches of all cultural perspectives.

For Asa Hilliard, "if the curriculum is centered in truth, it will be pluralistic" (Hilliard, 1991–1992, p. 13). The search for truth, he believes, must include "a critical orientation" that "implies an awareness of all cultural alternatives and a thoughtful and honest examination of those alternatives" (p. 13). Uniqueness and commonalty are not opposites but concepts that support each other. To address both, however, curriculum must be diverse. "Curriculum change must proceed first and foremost from the assumption that there is truth in the whole of human experience" (p. 14). James A. Banks (1991–1992, p. 34) adds that students must be taught "that knowledge is a social construction, that it reflects the perspectives, experiences and values of the people and cultures that construct it, and that it is dynamic, changing, and debated among knowledge creators and users."

Diversity and multiculturalism are words that are used in many different ways in education today. According to McLaren (1994), diversity cannot be used by the school as a consensus builder or a tool to build a false norm . In such a process the "mainstream" culture uses diversity to contain differences rather than to explore or liberate the basis of the diverse cultures of the school. Such practices are "additive" (Mohanty, 1994, p. 158). A school may add material that features people from minority groups in its pictures; it may recruit "diverse" faculty or administrators; it may use "diverse" curriculum units. Such adoptions do not transform instruction or the people in the school in a way that makes the natural world of those from the "diverse" cultures a central part of the school life. They do not address Hilliard's call for a "critical orientation" or Banks' focus on knowledge as a "social orientation" or Cornel West's (1993a) vision of an education that transforms the lives of students and teachers whether from minority groups or not.

Diversity and multiculturalism are more than a curriculum that values people and cultures. Equity and diversity must be personally mastered within the classroom by each child and teacher. Teachers have a responsibility to "create a small caring community in the classroom" (Bullard, 1991–1992, p. 7). Field trips to other neighborhoods and a focus on heroes and holidays will not transform a classroom in a school made up predominately of one ethnic or socio-economic group or one race. Teachers, administrators, students, and parents have to work constantly in such schools to make the question "whose culture?" a constant issue in and out of class (see Adams, Pardo, & Schniedewind, 1991–1992). (The terms *multiculturalism* and *diversity* will be dealt with again in Section 2.)

Equity as Special Services

While some educators see special services offered to specific children as a means toward equity, others see these same services as producing inequity.

Some educators believe that equity can be achieved when the special needs of particular groups—including gifted students, children with disabilities, children from specific racial and ethnic groups, and female students—are targeted within the school or the school system. Traditionally, schools have offered special programs, tracking, electives, special curricula, and similar responses. These offerings, however, have not always promoted equity and have sometimes produced inequities. Some educators argue, though, that special programs and services correct imbalances within and among previously underserved groups of students.

"Intervention programs in math and science are an effective means of increasing the participation of females and minorities in those disciplines" (Clewell, 1987, p. 119). Intervention programs are "educational programs that address a problem that is not being adequately addressed by the educational system" (Clewell, 1987, p. 95). The needs of gifted children, for example, are sometimes targeted through pull-out classes and sometimes by grouping within heterogeneous classes (Feldhusen, 1993). Children with mental and physical disabilities have also been placed in pull-out programs and often in separate schools. Heterogeneous grouping is now thought to be appropriate for most children, gifted or disabled; dissension still exists regarding how much of the school day should be spent in heterogeneous classes. Other types of special treatment can include enrichment classes and special tutoring programs.

Opponents of Equity

Whether they express outright hostility to equity or include some equity goals within their aims, some people fear equity as a form of leveling or as the perceived opposite of liberty.

Some fear equity as leveling or the destruction of legitimate differences, especially if financing is at stake. These critics of equity goals, as described by Jonathon Kozol (1992), believe that "democratizing opportunity will undermine diversity and even elegance in our society and that the best schools will be dragged down to a sullen norm, a mediocre middle ground of uniformity" (p. 172). For people who fear this possible leveling, local autonomy and control of schools guarantee liberty, even if the result is that children in districts with fewer resources suffer from extremely unequal educational conditions. Liberty and equity are, thus, seen as antithetical.

According to Kozol, many who claim to value "both equity and excellence in education" really do not want equity but "something that resembles equity but never reaches it" (p. 175). Michael W. Apple also believes that excellence can be a concept used by the opponents of equity to shift focus from the presumed failings of the schools and even of the larger society to the supposed failings of the individual student (Apple, 1989).

Equity in This Paper

The Southwest Consortium for the Improvement of Mathematics and Science Teaching defines equity in the most inclusive terms possible. From this perspective, equity means that each student is addressed on her or his own individual terms. Students "whose skills, strengths, and talents are necessarily diverse" will be treated individually and, thus, equitably (Greene, 1978, p. 128). Schools will be organized "around a sense of purpose and meaning that makes difference central" to understanding (Giroux, 1993, p. 174). The classroom interaction of teacher and student will acknowledge difference while working toward a deeper understanding of science and mathematics for each student and will be grounded in shared respect.

The pages that follow focus for the most part on students from ethnic minorities, women, and low-income students. In part, this focus is a function of the literature. Other "underrepresented" groups are also considered (for example, rural students and children with disabilities) but not in the depth of the first three groups. This, too, is a function of the literature.

CHAPTER 1.2 Equity as a Public Policy Issue

As science and mathematics affect more areas of everyday life, an aware citizenry that understands scientific and mathematical concepts becomes more important and the old view that science and mathematical education is only for an elite few has to be discarded.

Science seems destined to become ever more specialized and yet to affect the lives of people in increasingly profound ways. As its effects become more widespread, increased specialization can make science and its findings and workings increasingly incomprehensible to more people. Many educated people seem unable to distinguish between a scientific statement and pseudo-science or nonscience, such as astrology (Padian, 1993). Unless an effort is made to increase the voting public's scientific knowledge—and the mathematical skills that are critical to such understanding— scientists may find it difficult to receive public funding for research or to apply new discoveries and technologies in the marketplace. Such results would have strong effects on all aspects of our society. Perhaps more importantly, citizens will be making decisions they do not fully understand and they will be denied part of their intellectual heritage.

David L. Goodstein has likened scientific education in the United States to a "mining and sorting operation, designed to cast aside most of the mass of common human debris, but at the same time to discover and rescue diamonds in the rough, that are capable of being cleaned and cut and polished into glittering gems" (Goodstein, 1993, p. 27). This scientific elitism is not good, Goodstein adds, for science or nation. He holds that the purpose of science education from kindergarten to college should be "to produce citizens capable of operating a Jeffersonian democracy, and also if possible capable of contributing to their own and to the collective economic well being" (p. 27). Because students do not become Ph.D.-holding scientists does not mean the educational system has failed, but a system that emphasizes producing physics doctorates at the expense of a scientifically literate "laity" *is* failing. The African-American poet and educator June Jordan has called this process "finding the haystack in the needle" (Jordan, 1994, p. 89). "American education has venerated the needle and scorned the unruly, combustible, and gigantic haystack of our increasingly heterogeneous population" (p. 90).

An increasing number of scientific issues—such as the allocation of energy sources, the creation of synthetic life forms, the local ramifications of waste disposal techniques, and the uses and costs of new medical technologies—affect daily and public life. Public decisions have to be made about these issues and, unless science and mathematics are made accessible to more people, a largely uninformed public will be making these decisions (Weld, 1992). Curriculum and teaching methods must be devised to enable students of both genders and all races, abilities, and cultures to make these decisions on an informed basis.

CHAPTER 1.3 Equity as a Labor Force Issue

As the economy changes from one based in industrial production to one based in information production, the workplace reflects these changes. Students and their parents expect that education will help them to cope with these changes. The demographic groups that traditionally have not taken science and mathematics are now the fastest growing in the U.S. population. The implications of this demographic change for the work force are important and complex.

Just as an informed electorate and knowledgeable consumers need some knowledge of science, a well-trained work force will need scientific and mathematical ability. In the past when only the elite of a student body went on to study science and higher mathematics, "even those who dropped out could find well-paying unskilled jobs." As the economy becomes more automated and oriented toward high-technology industries, "those who fail in school are more likely to remain unemployed or in dead-end jobs" (Chira, 1993, p. E5).

The Changing Workplace

Most observers assume that long-term changes in the work force will require increasing access to science and mathematics instruction. The economic base of modern society is moving from industrial production to the creation and dissemination of information. Barbara S. Spector (1993) has called this move from the nineteenth-century industrial system to the information system a "paradigm shift." Michael Apple and Lois Weis have called the same process "de-industrialization" (Weis, 1990). Alain Tourine has called the resulting society the "programmed society" (Weis, 1990).

This shift to an information-based economy involves many economic changes, including a move from nationally based economic systems to a world economy and an opening up of multiple career options for workers and employers. These new systems change the workplace, the way money is invested, and the basis of power in society. Knowledge emerges as the most important form of power in the new economics of the information society and among the members of the labor force that will function within it (Toffler, 1991). Society must rethink the idea that "schools prepare students to occupy positions in the industrial order similar to those of their parents" (Weis, 1990, p. 4).

If knowledge is becoming the "essence of power," schools should, by rights, be the vanguard in the formation of this new culture and the shaping of the resulting work force. Assumptions formed during the industrial age, however, are still the dominant western world view, and schools embody and pass on that world view (Spector, 1993). Many schools still reflect the nineteenth-century McGuffey reader approach to learning that values the ability to follow instructions, an emphasis on industrial-like discipline within the classroom, standardization of material to be learned, and rigid conformance to rules that have been generated outside of the classroom. Many observers believe that these characteristics are not as valued in the evolving workplace as are creativity, the ability to think for oneself, and the ability to function well in small work groups.

Previous educational reform initiatives in this country, says Spector, have been disappointing because they stayed within the old industrial-society paradigm. Spector believes that new initiatives must "restructure schools cast in the new paradigm." This process will have to be ongoing because, as schools change, other aspects of society will also change in ways that will require further reforms in education in a constant on-going spiral (Spector, 1993).

Even within the manufacturing sector, available jobs depend increasingly on the use of skills that in the past were not important parts of manufacturing. Textile mills, for example, used to depend on relatively uncomplicated machinery. Newer looms, however, have microprocessors and other electronic components. "Repairing these machines requires an ability to follow complicated manuals and technical updates provided by manufacturers. As a result literacy skills are much more important in repairing looms today than in the past" (Murane & Levy, 1993, p.6).

Until the early 1970s reading and mathematics skills had little effect on the wages subsequently earned by male high school graduates who did not attend college (Murane & Levy, 1993). In the 1970s and 1980s white male workers with relatively few skills—handlers, service workers, factory operators—lost economic ground in relation to managers, professionals, and other white-collar workers (Blackburn, Bloom, & Freeman, 1990). While people trained in science-related fields have generally entered a growing labor market, in the last decade that market also appears to have begun to shrink (Kilborn, 1993). These workplace changes will radically affect education.

The literature suggests that in the future all sectors of the economy will emphasize greater understanding of basic concepts of science and mathematics. At the same time fewer jobs that focus on science and mathematics in themselves may be available. Elites with in-depth knowledge of science and mathematics may be in less demand, but generalists who have a good grasp of these areas may be in great demand. Students will need to be able to relearn not only their jobs but also the world around them if they are to function in the future workplace and society.

The Changing Work Force

The work force confronting these cultural and workplace changes will be overwhelmingly *not* made up of white males. By 2050 the four largest minority groups—African Americans, Hispanics, Asian/Pacific Islanders, and Native Americans—will account for nearly half the U.S. population, according to a report issued by the Population Reference Bureau (PRB) (*Education Daily* 25 March 1993). In 1990 the Los Angeles population was 40 percent foreign born; 49.9 percent of city residents did not speak English as the first language in their homes (González, 1993, p. 257).

The transition from a population dominated by European Americans to one made up of many different racial and ethnic groups will be manifested in the schools even before it is expressed in the general population. The PRB forecasts that by 2035 more than half of all people below 18 in the United States will be from an ethnic minority group. In addition to the increase in specific minority groups, racial blending is also increasing, according to the PRB. Between 1968 and 1989 children born to parents of different races increased fourfold in the United States (*Education Daily*, 25 March 1993).

These population changes affect school instruction and issues of equity regarding science and mathematics education. The racial and ethnic groups that have been traditionally underrepresented in science and mathematics are the population segments that are growing most rapidly. The United States apparently does an excellent job of educating the few. When it comes to educating those in the lower learning percentiles and in poorer socio-economic brackets, however, the United States may fail as drastically as countries that do not claim to educate more than the top elite. Further research is needed, however, if comparisons among countries are to function as more than "scare statistics" (see Bracey, 1993; Sandia National Laboratories, 1993).

Lawrence Mishel and Ruy A. Teixeira (1991), writing for the Economic Policy Institute, disagree with the views of most observers regarding the future labor market. They do not believe that ensuring that more people have higher skill levels will be an adequate response to the emerging labor market (p. 40). They also believe that non-Hispanic whites will be the majority of entrants into the labor market in the 1990s. They see a developing work force dominated by whites, male and female, with a steady demand for high-level skills that is less than the demand other sources have predicted. Even so, they join other observers in seeing an increasing role for minority groups in the labor market and a need to "raise the high school and college completion rates of minorities" and to improve the basic skills of all students (Mishel & Teixeira, 1991).

CHAPTER 1.4 Equity as a Moral Issue

If science and mathematics contain information and knowledge that is valuable in present-day society, then equity in teaching and learning those subjects is a moral issue. Educators must also be concerned about the uses of science and mathematical knowledge in the larger society.

Equity is a moral issue. If the United States is truly a pluralistic society, one goal of the education system must be to include and to value all segments of that society. Science and mathematics are culturally valuable components of knowledge that, given the assumptions of our society regarding equality and democracy, should be available to all. The classroom of a public school is an "involuntary civil community" (Garcia, 1991, p. 206). Students, up to a certain age, have few or no choices in attending school—they cannot choose their teachers and have little control over the subject matter they are taught. If schools are to be "liberating forces in the lives of their students" (Garcia, 1991, p. 215), all students deserve to be met with high expectations that preclude mediocrity.

What is the purpose of this education? Is it to ensure that the country has a constant supply of people able to fill certain jobs? Or is it to make a body of knowledge available to students? Or is it to help students live more fulfilling lives as adults?

Michael Apple and Lois Weis have pointed out that "the very notion of the educational system as assisting in the production of economically and ideologically useful knowledge points to the fact that schools are *cultural* as well as economic institutions" (Apple & Weis, 1986, p. 11). In their view when one group's knowledge is valued because it can be useful, the knowledge and traditions of other groups in turn "are considered inappropriate as school knowledge" (p. 11). In this way schools reproduce the culture and ideology of the dominant groups in society. The economic, cultural, and political spheres of life are "constituted by the dynamics of class, race, and gender" (p. 23). Schools' valuation of science and mathematics, Apple and Weis argue, can be seen as part of the process of continuing the domination of a particular culture—European American and male—in the United States.

Gerard Fourez has phrased the question in a more global form in his essay in *Scientific Literacy* (Champagne et al., 1989, pp. 105–106):

> Could it be possible that promoting a scientific culture would not increase the autonomy of individuals but ultimately would integrate them into a more programmed society in the name of scientific rationality and would subject them to the economic and political interests of the corporate world or—what could be even more disquieting—to the interests of a privileged minority?...scientific literacy is not simply a disinterested business: power, money, autonomy and status are all at stake.

Charles Handy (1994) has cast doubt on the future willingness of those who now possess power and control of information to share it with those who do not. Do the knowledge possessors of the present and the future have any incentive to invest in public education and increase the supply of people who can perform their well-paid functions? Perhaps their self-interest is bound up in keeping as many people as possible *out* of the education that will give them access to the command of science, technology, and information. Might not knowledge handlers have a vested interest in continuing the them–us dichotomy that will enable those who now manipulate information to maintain that control? Those whose property is knowledge do not need to sell their products to others as did those whose products were cars or corn. Information dealers can sell only to each other and still profit, according to Handy. The evolving society may have more incentives than did the old to construct stereotypes, continue inequalities, and see "others" in those it has excluded (West, 1993b; Giroux, 1993).

CHAPTER 1.5 Culture and Equity

The cultures of the larger community, the school, and the home all shape the ways in which students learn and perceive science and mathematics—and the ways in which educators, parents, and students themselves perceive students' interests, abilities, and needs.

Many observers of education believe that problems in achieving equity are embodied in the very culture of schools and in the cultures of the larger society and the various groups within it. The larger culture makes "whiteness" seem to be outside of ethnic categories and in this way makes nonwhite groups into "others" (Giroux, 1994). A sense of superiority, or at least difference, from others on the basis of race, gender, language, culture, ethnicity, or religion can render those "others" invisible when norms and standards are devised. Culture is seen as "noncontradictory...a storehouse of nonchanging facts, behaviors, and practices" (Mohanty, 1994, p. 158). "White" culture then becomes the norm and this subtle and deep view of what "should be" becomes a part of the lives not only of most European Americans but also of people from other racial groups.

The culture of a school exists within the larger community, but each school forms its own culture from the larger culture and from the beliefs and behavior of its students, teachers, administrators, and others who come into contact with the school's life. Each school, however, devises a different way of dealing with its larger community and with the relationships between students, teachers, administrators, and the community.

Hugh Mehan, for example, sees culture as relatively autonomous in determining inequality in the schools. "Peer associations and family life, cultural forms and practices" are not, he holds, passive factors in, but active shapers of, a child's educational success (Mehan, 1992, p. 15). Attitudes toward science and mathematics are part of our national culture. As Ronald Parker, a physicist at the Massachusetts Institute of Technology puts it: "Real men don't do science, real women don't even think about it" (Begley, 1990, p. 64). Science and mathematics education from kindergarten to college fares poorly among all children because society values other callings as more glamorous, intriguing, and productive.

While most children come to school with a robust interest in the world around them, by third grade half no longer want to take science, according to Edward Pizzini, associate professor of science education at the University of Iowa (Cowley, 1990, p. 53). According to Joseph V. Stewart of the National Science Foundation, by tenth grade, "most students see scientists as destructive nerds" (*Eisenhower Links 1992: Conference Report, December 6-9, 1992*). By college graduation only 9 percent of males and 4 percent of females are interested in being scientists or engineers.

The cultural forces that keep poor, minority, and female students out of science and mathematics classes—and keep them marginal participants in the classes to which they *do* have access—are many. These influences include inferior elementary education, their teachers' low expectations, anti-intellectual peer pressure, and the cultural gap between the world of scientific research and their daily lives. European-American affluent male students have to deal with these same forces, and the majority of white males also avoid science and mathematics as they progress through their school years. Cultural conditioning to compete, to succeed, to play the school game and to win, however, helps some white male students to see that they may be rewarded if they play by the unwritten rules of the school game. This possibility of a reward and the conditioning of the culture help keep some white males at least superficially engaged in schoolwork. European-American affluent male students have long believed that if they play the school game correctly they will be rewarded. This belief is not usually shared by minority, female, or poor students.

Home culture can often make a difference in preparing children for school and its expectations. Many parents, intentionally or not, present everyday events as lessons for their children ("How many eyes does the doggie have?"). Their conversations and interactions even with very young children may be "studded with test questions, requiring children to retrieve facts, evaluate the accuracy of statements and...problem-solve" (Scholnick, 1988, p. 86). Research indicates that academically supportive families function in the same ways no matter what socio-economic or ethnic group they come from. Parental interactions in such families often focus on future possibilities or relations between discrete events in a way that aids the child in learning to think abstractly. Such parents may ask more questions—and expect answers— of the child, and these questions will be similar to those the child will be asked in school (Mehan, 1992). Children who grow up in academically supportive homes are better prepared for the demands of the usual classroom than are children whose parents do not practice such conversational techniques—who often have to learn new forms of communication in school (Mehan, 1992). Generally speaking, the children of poorly educated parents will not grow up in academically supportive environments. The cycle of doing poorly in school, dropping out, and other negative school behaviors, thus, continues within families.

No matter what demographic group the family appears to belong to, an academically supportive family prepares children for the questioning styles and other cognitive patterns of school. Once in school "comprehending the new style places an additional burden on the child who is also mastering the conceptual content of arithmetic" (Scholnick, 1988, p. 86). Independent of socio-economic class, "parents of low achievers tend to see the world around them as unmanageable and devoid of opportunities for self-improvement" (Slaughter & Epps, 1987, p. 18). Such parents also tend to avoid contact with school personnel. While these interactional styles are found across the socio-economic range, most frequently "the language use of middle-income parents matches the often implicit and tacit demands of the classroom," while "the language use of low-income parents does not match the discourse of the classroom" (Mehan, 1992, p. 7). Home language use becomes even more problematic for school success when that language is not English.

CHAPTER 1.6 Rethinking Reform Efforts

In the past, educational reform efforts have focused more on the problems faced by European-American males, such as low reading scores, than on those faced by children from minority groups and females, such as difficulties with science and mathematics.

Educational reform efforts have not addressed the academic problems faced by members of minority groups and by females of every race and ethnicity as well as they have the problems that beset European-American males. Federal money, for example, has been spent in great amounts to improve low reading scores, a problem that boys face five times more often than girls (Sadker, Sadker, & Steindam, 1989). Reading is seen as basic to educational achievement, but the problems with mathematics and science that females and minority students frequently face have not received the same governmental and budgetary attention. "To ensure all America's children a window of opportunity in the nation's classrooms, a *reformed* movement should address the academic deficits of girls and minorities with the same fervor and finances devoted to resolving academic problems that historically plague boys" (Sadker, Sadker, & Steindam, 1989, pp. 46-47).

At all educational levels, previous attempts to reform education in order to benefit minorities and women appear to have failed. Calvin Sims (1992), business and technology reporter for the *New York Times*, attributes these failures to several factors:

- programs were not adequately supervised or assessed;
- most programs targeted college-age students not elementary and high school students, who might have benefited more;
- funding was inconsistent and not connected to results;
- administrators and faculty were not committed to these programs;
- goals were vague or unrealistic;
- psychological issues, such as teachers' low expectations, were usually ignored;
- unprepared students were often recruited into programs and then given no ongoing support.

In addition to these basic problems, traditional ideas of educational reform may bear rethinking at a philosophical level. Sheila Tobias (1992) warns that problem hunting and solving may lead to reductionism, to favoring theoretical and universal solutions over incremental changes, or to the temptation to believe that all problems can be solved with products. "Reform is not a scientific enterprise, and educators should aim for not the experimental model, not the research model, but a process model" (pp. 93). Reform will be more effective, she adds, if educators at all levels cooperate with each other and make direct contributions to decisions and if strategies for reform are fashioned by those working at the institution undergoing reform.

PART 2:

Issues Involved in Equity

Current thinking about reforming U.S. science and mathematics education to make it more equitable has focused on a series of salient issues including

language ability;
the **structure of schools**, which includes such items as tracking of certain students, course access, and fiscal equity;
teacher expectations and behavior;
curriculum;
instructional approaches;
assessment of both students and programs;
cultural effects both inside and outside of school.

These issues are all interwoven. While they will be discussed separately in the pages that follow, the reader must remember that they cannot in reality be tackled as isolated causes or effects.

CHAPTER 2.1 *Language Ability*

Language is an issue in mathematics and science education. Many studies have shown that students cannot easily learn mathematics and science when it is taught in a language other than their own. Bilingual education is one approach to the difficulties caused when students come from non-English-speaking backgrounds. Students who speak Black English may face special problems.

Language is more than a cultural artifact, especially when it is not the "politically dominant language" of the country (Secada, 1992, p. 643). Many Hispanic, Native American, and Asian students often must try to learn mathematics and science content that is presented in a language they do not—or at least do not easily—comprehend.

LEP Students and Bilingual Education

Some students are monolingual in a language other than English; many are bilingual. Some are labeled as having limited English proficiency (LEP). The *Thesaurus of ERIC Descriptors* defines those with limited English proficiency as "individuals who know English as a foreign language without sufficient proficiency to participate fully in an English-speaking society" (Houston, 1990, p. 150). Walter Secada (1992, p. 627) has noted that, while definitions of LEP differ from state to state, most definitions share some characteristics:

> there is a language other than English in the student's social milieu (usually at home, but a broader setting may be given), that the language in question has had some impact on the student (ranging from the student's having some understanding of it to being monolingual in that language), that the student is not fluent in English, and that the student's academic performance suffers as a result of that limited fluency.

Language ability is contextual. A student may be competent in English on the baseball diamond but not in the physics laboratory. Some students who are classified as LEP are often proficient in English in an everyday setting but may not be able to use the language in an academic setting (Pimm, 1987). Many schools, however, use language as a proxy for ability. The assumption is that students whose English is not "standard" must be held back, placed in special education, or in some other way dealt with in a special manner. Science and mathematics educators often assume that students must know English before they can be taught content. How children are to be taught English has often become a politically contentious issue, usually focused on bilingual education.

A longitudinal study of 58 classrooms that enrolled LEP students who spoke Spanish, Chinese, and Navajo identified five characteristics of effective bilingual instruction: The teacher must use active teaching strategies. The teacher must be able to alternate between the two languages when necessary. English skills must be integrated with content. The students' cultural norms for behavior and communication must be used in the classroom,. Finally, the organization of instruction must be congruent with the intention of the instruction (Tikunoff, 1985). Other studies have indicated that LEP students probably do better in mathematics if they receive instruction in their native language, but the processes that result in mathematics proficiency for LEP students are still not well understood (Secada, 1992).

William L. Leap has suggested that "Ute students approach mathematical problem-solving tasks by reference to...language-related assumptions and strategies" (Leap, 1988, p. 184). Leap's recommendations are based on specific Ute characteristics that he identified in his research. More generally, however, his work suggests that teachers cannot lump groups of students together in devising teaching strategies; each student's needs will have to be analyzed and met.

Black English Vernacular

The language difficulties of LEP and other language-minority students in U. S. schools are relatively easy to spot, however, compared to the language incomprehension encountered by some African-American students. Eleanor Wilson Orr, co-founder of the Hawthorne School—

an experimental private school in Washington, D.C.—has traced problems with mathematics faced by some African-American students to concepts arising from Black English Vernacular. She had taught at the Hawthorne School for some time before she realized that "nonstandard *perceptions* could accompany...nonstandard usage—perceptions that might lie at the root of some of the difficulties the students were having" (Orr, 1989, p. 31)

Especially at the level of preposition use, comparisons, and some other basic structures of language, Black English Vernacular may depart significantly from the English used by white middle-class teachers. Teachers often miss the fact that students who use this dialect may have understandings of relations between numbers and other mathematical concepts that differ from those presented by the teacher's English. Perceptions about such categories as distance and location that have been formed by usage may affect the way students answer mathematics questions. Orr found that students had trained themselves to use "proper" English but did not have "the understanding one might assume to underlie the use of the words" (Orr, 1989, p. 40). By making students explain precisely the specifics of an algebraic statement, she found that student words gradually came into better contact with their thinking. "Language then begins to become something a student thinks with instead of something he or she performs in order to be correct" (Orr, 1989, p. 40).

Until a teacher learns how to find out why students make mistakes, language-based misunderstandings will continue. "I want to stress how much of what a student is actually thinking can remain hidden because one tends to assume one knows what a student means by what he or she says in spite of the way he or she says it. The tendency is to see the student's words in relation to what one is thinking oneself" (Orr, 1989, p. 30). The students need new verbal tools and they "must encounter these verbal tools when they need them—when they are engrossed in trying to figure something out" (p. 205).

On a larger and more general level, students are silenced in schools. They cannot find or use their voices (Fine, 1989). This silence makes the life experiences of students irrelevant to schooling and cuts them off from the community around them. Diligent students train themselves to use a school voice that is not authentic to them. To succeed in school they must cut off their own expression.

CHAPTER 2.2 The Structure of Schooling

By its very structure, schooling may deny some students opportunities in science and mathematics. Students can be denied basic opportunities to learn science and mathematics by the tracking system used in many schools and by concepts regarding course access held by educators, students, and parents.

High Track, Low Track

More minority and poor children than middle-class white students are placed in low-track classes, which do not allow for subsequent access to advanced courses. Many believe that the tracking system does not benefit anyone, even those placed in high-track classes. Some, however, point to educational benefits of special classes for gifted students.

In a study conducted by the Rand Corporation and sponsored by the National Science Foundation, Jeannie Oakes (1990b) reported that many students are not allowed access to higher-level science and mathematics instruction because of tracking. Channeled into high-track or low-track classes, students find it difficult to jump these tracks. Once on the low track students do not have access to the kinds of science and mathematics instruction that will enable them to consider higher education or careers that require mathematics and science knowledge. Students on the low track may also have teachers who have been tracked themselves—they tend to be lower in the teacher hierarchy and to have less relevant experience. Low-track classes spend more time on class routines and discipline and less time actively learning the subject matter.

Students from minority groups are seven times more likely than white students to be identified as having low abilities (Oakes, 1990b) and, thus, to be placed in low-track classes. This likelihood increases in secondary school. In high school the pattern of diminished opportunities grows more entrenched since students on the low track are more likely to be placed in vocational and general programs where they study only basic and applied mathematics and science. Their classes have more rote learning with fewer opportunities to use critical and independent thinking skills than will be offered to students on the higher tracks. In low-track classes the instruction is characterized as "oversimplified, repetitive, and fragmentized" (Oakes, 1990b, p. 89) and less time is spent on actual work. Students on the low track must show extraordinary initiative and diligence if they are to escape from the direction that tracking ordains for them. That direction is not toward higher education or greater individual autonomy.

Students who are shunted to low-track courses are denied access to so-called gatekeeper courses, which must be taken to prepare them for college-level mathematics and science courses. These college-preparatory classes are more likely to be taken by white students than by students from minority groups. The Rand study found that junior high schools with predominately white student bodies are more likely to offer college-preparatory mathematics classes than are junior high schools with predominately minority populations. Primarily white high schools are also more likely to offer calculus than are predominately minority high schools. Middle and junior high schools with more white students tend to have four science classes available for every 100 students, while schools with more students from minority groups have about 2.5 such classes for every 100 students and tend to have more students in each class (Oakes, 1990b).

The tracking system was ostensibly established so that high achievers would not be held back by students who worked at a slower pace. The Rand Study indicates, however, that high achievers do just as well in a mixed ability class as they do in a high-track class. The fundamental stated reason for such classes, then, according to Oakes, is not valid. The Rand report concludes that no empirical evidence justified "unequaled access to valued science and mathematics curriculum, instruction, and teachers" (p. xi).

The National Council of Teachers of Mathematics (NCTM) cites other research that bears out the view that heterogeneous study groups are more fruitful for students and teachers alike. The council points out that tracking in elementary and secondary mathematics is based on ability to compute. "However, computational competence is not always a valid measure for success at advanced levels of mathematics. Hypothesizing, approximating, estimating, reasoning, problem solving, and communicating are skills and abilities not often tapped through traditional computational work" (NCTM, 1991, p. 1460).

Not everyone agrees that heterogeneous classrooms are better for all children—especially talented and gifted children. James A. Kulik and Chen-Lin C. Kulik found that when students in the same grade are grouped in separate classrooms by aptitude the benefits are small. When tracking systems place "talented" students in separate classrooms the Kuliks found clearer benefits for most students (Kulik & Kulik, 1987, p. 22). Writing in the third volume of *Critical Issues in Gifted Education*, Janet Conroy has argued that the major concern in placing gifted children in heterogeneous classrooms is saving money. She likens children gifted in science and mathematics to children who are gifted athletes or musicians and receive special training (Conroy, 1993).

The tracking system, as usually practiced, perpetuates a gap between students, predominately white, who are placed in high-track classes and students, generally from minority groups, placed in low-track classes. In 1976 Samuel Bowles and Herbert Gintis argued that tracking maintains and reproduces the existing class structure of society (Bowles & Gintis, 1976). In 1992 Joseph Conforti took the Bowles-Gintis thesis a step further and held that tracking "not only reflects and sustains social class inequality in American society, but that it also serves as a major mechanism for legitimating such inequality....Such legitimization derives from the culturally shared belief that American society should be organized as a contest society" (Conforti, 1992, p.230).

Whenever a contest is accepted as the basis of interaction, inequality is also accepted: "To enter a contest is to accept the possibility of losing, which already comes close to accepting the legitimacy of inequality" (Conforti, 1992, p. 231). Children are socialized early to the idea that rewards are few and the contest is valid, so most people must accept the idea that they will lose. This socialization allows the losers in the contests to accept the validity of lower ranks for themselves. The "socialization to inequality" prepares children for "unequal positions" and encourages them to accept these positions as "fair and just" (p. 232). Students begin to accept their differentiation into ranks, and this acceptance is seen as "being in keeping with American ideals of individual effort and individual outcomes of success and failure" (p. 235). For Conforti the tracking system and the socialization to a contest mentality perpetuate inequality of both opportunity and outcomes in the education system.

Tracking is not the same thing as grouping. Within a heterogeneous classroom a teacher can group children into sections by skills or interests for all or part of each day. According to Sharon Hooker (1993), p. 59), "grouping children for cooperative learning experiences has been found to promote positive interaction patterns, feelings of psychological acceptance and psychological success, liking for other students and the instructor, and expectations of rewarding future interactions with collaborators."

Robert E. Slavin (1987) found grouping to be beneficial if students stayed in heterogeneous classes for most of the day and were placed in only one or two smaller groups where the pace and level of instruction were "completely adapted to student performance level"(p. 33). The most effective learning, he holds, combines cooperative learning and ability grouping. Students in heterogeneous groups check each other's work and help each other. From these cooperative groups, the teacher calls out ability groups to work on specific problems. After these smaller group lessons, students return to their heterogeneous teams. For Slavin the possibility that students "need to have material taught at their level in certain subjects, such as mathematics and reading, does not force us to any particular form of institutional grouping" (p. 35). While the more common forms of tracking have been shown to be ineffective, Slavin believes, alternative methods must not only increase learning but also improve relationships between students from different ethnic and socio-economic groups.

Access to Courses for Gifted Students

Educators and parents construct images of gifted children that can blind them to the actual abilities of children from minority, poor, and other underrepresented groups.

Access to classes for gifted students is not proportionately distributed across the population. How teachers, administrators, and parents view the specific children involved and the adults' mental images of gifted children define whether certain children will or will not be seen as "gifted." Once identified, such children may be tracked into special classes or they may be put into classes where they will be grouped with other children of similar abilities or given special one-on-one attention by the teacher.

The NCTM has recommended that all students who are gifted in mathematics should be enrolled in some kind of program with "a broad and enriched view of mathematics in a context of higher expectation" (NCTM, 1992b, p. 19). NCTM promotes the idea that school districts have a responsibility to identify gifted students and to design and offer programs that fulfill their needs. According to NCTM, teachers, counselors, administrators, and other professional staff members should consider not only the student's mathematical ability but the student's entire educational development when deciding what students should be identified as gifted. The council recommends that mathematically gifted students be offered "enriched and expanded curricula" that emphasize higher-order thinking skills, nontraditional topics, and applications in many contexts. Only students clearly interested in continuing in the program and excelling should be allowed to accelerate through these programs (NCTM, 1992).

The NCTM has no explicit statements regarding how teachers and administrators are to identify gifted children from minority groups or other traditionally underrepresented groups. According to most of the literature, identifying gifted students who do not fit the stereotypes of people who are good at mathematics and science requires different assessments and careful observations from teachers to discover abilities that may be clouded by socio-economic or other factors.

While some have argued that standardized tests are important in identifying gifted students from minority groups, especially gifted African-American students (Van Tassel-Baska, 1986), others have presented documentation that suggests standardized tests are administered inappropriately for gifted African Americans (summarized in Frasier, 1989a). Leland Baska (1989) and Richard Ronvik (1989) both believe that standardized tests should be retained for identifying gifted African-American students because some teachers will not identify black children as gifted unless they have such verification.

Standardized tests specifically for assessing the giftedness of students from linguistic minority groups may be available, but by and large publishing companies have shown little interest in developing instruments in languages other than English, especially in those languages with a low incidence in this country. When such instruments have been developed they have been very expensive. In any event, other assessments, such as interviews, case studies, observations, or student presentations, may be more helpful in identifying gifted students from language minority groups (Zappia, 1989; Chen, 1989; Kirschenbaum, 1989). A problem with this approach, however, is the lack of trained personnel who understand both assessment of gifted children and the child's language and culture.

Educators will do best if they move away from traditional criteria for identifying gifted children, such as standardized tests, and "use multiple assessment procedures, including objective and subjective data from a variety of sources" (Maker, 1989, p. 295). Culturally and linguistically appropriate assessments and more than one identifying source—including parents, past and present teachers, other students, people from the community, and the students themselves—should be used. Because each child is different, a case study approach—based on many sources of data and interpreted in the context of the student's life by a team rather than one person—may be the most useful in identifying gifted children (p. 296).

Cultural characteristics and language often make identification of gifted students difficult for an educator who has not picked up on cultural clues or does not understand the student's native language. Gifted students who are not middle class or European American may be less verbal and more passive in class than gifted children who are middle-class and white. Time limitations may have little effect on them and they may perform better on nonverbal tests, while those traditionally identified as gifted students may perform equally well on both verbal and nonverbal tests (*Education Daily*, 13 May 1993).

Students with limited proficiency in English are disproportionately placed in remedial classes and are not placed in classes for gifted children in numbers that reflect their proportion of the population. This disproportion has led some educators and children's advocates to call for creating heterogeneous classrooms and eliminating ability grouping. If education of gifted children is to occur in the heterogeneous classroom, however, those concerned with education for the gifted "must concentrate on helping the regular teacher organize and differentiate instruction, individualize the curriculum, and manage behavior and interactions in ways that improve education for gifted children within a diverse, heterogeneous, multicultural classroom" (McDaniel, 1993, p. 17).

Most children with limited English proficiencies are placed in "programs that focus on developing abilities valued by the majority culture"—usually bilingual education or English-as-a-second-language (ESL) classes (Banda, 1989, p. 27). Higher-order thinking skills are seldom taught in these classes. Once they have finished bilingual or ESL classes, children with limited English proficiency are often routinely placed in remedial classes regardless of their true intellectual abilities (*Education Week* 26 May 1993). Ernesto Bernal (1989) stresses the importance of developing the native language skills of bilingual students. "Certain cognitive advantages seem to accrue to individuals who become proficient bilinguals" (p. 35). Programs for gifted children would do well to foster this ability.

June Maker, associate professor of special education at the University of Arizona, believes not only that many students who are not in gifted classes should be, but also that many students who are in these classes should not be (*Education Week* , 26 May 1993). The latter group, she says, is made up of students who are high achievers because of their socio-economic backgrounds rather than being gifted students. Their educational needs may not be met in the best possible way by these classes and they may be displacing other students who could benefit from them. Many children from less advantaged backgrounds may enter school with less practice in writing, reading, drawing, and other primary skills and may be passed over for gifted classes despite their abilities. By adhering to stereotypes of the characteristics of gifted children, schools frequently turn programs for gifted children into "a third track" that, in essence, further segregates schooling (Kozol, 1992).

Beverly J. Irby, assistant professor of curriculum and instruction at Sam Houston State University, has constructed a profile of gifted Hispanic children from data on 6,000 Texas children. The study focuses on children who have been placed in gifted programs and indicates that Hispanic children who are identified as gifted appear to be more acculturated to mainstream U. S. culture than are other Hispanic children (*Education Week,* 26 May 1993). Children who adopt a "mainstream interaction and communication style" (Garrison, 1989, pp. 120–121) may succeed in the teacher's eyes, but often success comes at the expense of the child. "Culturally different students' ethnic identity may be jeopardized when they enter a program for the gifted" (p. 120). Frequently, they are perceived by their peers as putting on airs and distancing themselves from old friends. Unless teachers are aware of such reactions, they may find gifted students from minority groups leaving their programs.

Access to Special Education

Students who test the same on standardized tests are often treated differently when teachers and administrators decide who needs special education services. Even ostensibly objective tests must be interpreted, and children may be sorted in ways that have little to do with their abilities and needs.

Special education is another area in which the mix of students is disproportionate and equal access may be lacking for some students who need services. All studies indicate that boys outnumber girls in special education programs. In 1988 two-thirds of all students in such programs in the United States were male. The traditional explanation for this disproportion has been that males are born with more educational disabilities. Recent research by the Wellesley College for Research on Women, however, reveals that medical reports of learning disabilities and attention-deficit disorders are almost equally divided between boys and girls. Girls who are identified as learning disabled by schools usually have lower IQs than boys who are so identified. Educators may be reacting to perceptions of behavioral problems rather than to actual learning problems: Girls who are quiet may not be diagnosed as having a learning problem when they actually do, and boys who act unruly in class may be placed in special programs. Both sexes are misserved by this process: Girls who need help do not receive it and boys are mislabeled and placed in programs that do not deal with their needs (American Association of University Women, 1992).

Enrollment in special education is disproportionately high for minority groups also. According to the Public Education Association of New York, African Americans are disproportionately found in classes for children with emotional disabilities, neurological impairments, learning disabilities, and mental retardation, while Hispanic children are disproportionately in classes devoted to speech, language, and hearing impairments (cited in Kozol, 1992). Kozol has noted that, in the United States, African-American children are three times as likely as European-American children to be in classes for the mentally retarded.

Students who test the same on objective tests are often treated differently. "White, female, middle-class students who scored 80 or below were more likely to be retained in regular academic programs than were Black, male, lower-class students who scored the same on the IQ test" (Mehan, 1992, p. 12). Hugh Mehan concludes that mental retardation and other special education categories are constructed by the schools and teachers, working from their cultural and institutional views. "Certainly one would argue that a student who is confined to a wheelchair is handicapped or has a handicap. However, such a student would not automatically be placed in a special education program for the physically handicapped. Institutional practices for identifying and placing students have to be put in motion for students to be so designated" (Mehan, 1992, p. 15). The disproportionate numbers of poor, male, and ethnic minority students in special education classes suggest that many are picked out by the school's "sorting machine" for reasons that have little to do with the students' actual conditions.

Access to Counseling and Advising

Counselors may steer females and students from minority groups away from demanding science and mathematics courses because of their perceptions of the students' needs in later life. "Wise" schooling on the part of counselors

and other adults could help students move beyond the vulnerability they feel in school.

Regardless of race and class, female students take fewer demanding mathematics and science classes than do their male counterparts. Advisors and cultural expectations frequently steer girls away from these courses. Females are advised that they risk harming their grade point averages if they take more rigorous courses. Many counselors, teachers, and parents believe that female students will have little or no use for advanced science and mathematics courses in the higher education and careers that they envision female students pursuing. Frequently, even academically motivated female students who initially were interested in science and mathematics end up taking only the minimum of science and mathematics courses required for college placement (Alper, 1993).

The "most overt" counseling practice that results in discouraging female students from some courses is the use of vocational-interest tests that have sex-specific norms (Oakes, 1990a, p. 45). Counselors then use the tests to advise students about courses and career choices and to caution females against science and mathematics courses. Counselors are more likely to inform a male who does well on such tests about engineering careers than they are to inform females in similar situations (Oakes, 1990a). Counselors also tend to steer students with disabilities away from science classes because they believe the students cannot function in a laboratory (Oakes, 1990a). Students from minority groups and lower socio-economic groups often have less access to counselors; more affluent schools usually have more counselors than do less well-off schools.

Students from minority groups and disadvantaged backgrounds may need counselors and advisors more than do white students. Claude M. Steele has identified the process he calls "identification with school" as important to doing well. "Doing well in school requires a belief that school achievement can be a promising basis of self-esteem, and that belief needs constant reaffirmation even for advantaged students" (Steele, 1992, p. 72). Nathan McCall has described the process of de-identification with school. He was the only member of his family to attend a predominately white junior high school. While the rest of the children came home with stories of pep rallies and football games, he had humiliation and invisibility to report. His classmates and teachers alternately berated him, picked fights with him, or ignored his existence. A child who had initially been excited by school now reported that he "staggered, numb and withdrawn, through each school day and hurried from my last class, gym, without showering so that I wouldn't miss the only bus headed home" (McCall, 1994, p. 19).

The vulnerability of students can be eased somewhat, Steele believes, if counselors, among other adults, can be "wise." Being wise in this context means that the counselor realizes the full humanity of students from minority groups and is recognized by the students as someone who acknowledges their humanity. Steele sees "wise schooling"— which can only come from the adults in the school— as a major component in easing the vulnerabilities not only of African Americans in school, but also of other minority and poor students and of females who choose traditionally male-dominated areas of study.

CHAPTER 2.3 Resource Inequities

Poorer School Districts

Dependence on the local tax base has created fiscal inequities among U. S. schools. Wealthier districts can tax at a lower rate and spend more on each student than poorer districts. As a result, many inner-city schools lack basic physical requirements and are unprepared for new instructional technologies.

The financial means of a student's school or district also affects access to effective science and mathematics instruction. Resource inequities between advantaged and disadvantaged districts are an ongoing problem especially for science and mathematics classes, which often are perceived as requiring greater financial investment than other classes. Wealthier schools and districts tend to have students from more advantaged backgrounds to begin with and can afford to build on this base with equipment, libraries, and other materials.

Resource problems are often more basic than a need for calculators and balances, however. Many older schools and schools in low-income districts lack adequate electricity, roofs that hold out the rain, adequate sewage facilities, and other basic physical requirements. The use of technology to address educational problems is not realistic for many inner city and rural schools. How will schools that do not have telephone lines in classrooms handle new instructional methods that use telecommunications? How can a classroom with two electrical outlets run computers and other instructional machines? If a school uses alternative assessments how will portfolios be stored so privacy can be protected but staff members can use them? The typical elementary school of 600 children will require 100 four-door file cabinets to store portfolios (Schneider, 1993).

Probably about 75 percent of U. S. schools are inadequate, from a physical standpoint, for alternative education methods (Schneider, 1993). About 31 percent of existing schools were built before World War II and about 43 percent were built in the 1950s and 1960s. Most subsequent building occurred in the suburbs in response to population pressures. Suburban schools, therefore, are in a better physical position to take advantage of alternative teaching methods and systemic reform than are inner-city and rural schools.

Wealthy school districts can afford to have low tax rates and still manage to spend a higher amount on each pupil than poorer districts. Poorer districts, with limited tax bases, must levy at higher tax rates in order to meet minimum requirements. Wealthier districts can tax their more expensive properties at a lower rate and still have money left over after they have met the minimum the state requires. In Texas, for example, in 1985–1986 the 100 poorest districts had an average property tax rate of 74.5 cents and spent an average of $2,978 on each student. The 100 wealthiest districts, however, had an average property tax rate of 47 cents and spent an average of $7,233 on each student (Mauzy, 1989). In his dissenting opinion to the U. S. Supreme Court decision on San Antonio Independent School District *vs.* Rodriguez, Justice Thurgood Marshall stated that if "Texas had a system truly dedicated to local fiscal control one would expect the quality of the educational opportunity provided in each district to vary with the decision of the voters in that district as to the level of sacrifice they wish to make for public education. In fact, the Texas scheme produces precisely the opposite result" (quoted in Kozol, 1992, p. 219). The Texas scheme allows richer districts to avoid making sacrifices while enjoying a high standard of public education and forces poorer districts to make extensive sacrifices for a much lower standard.

Isolated School Districts

Rural school districts often lack a strong financial base, have difficulty attracting well-prepared staff, and tend to serve either a very small, sparsely distributed population or large widely spread-out districts.

While the financial problems of inner-city school districts have received at least some notice on the national agenda, isolated, rural schools frequently seem to be forgotten. The financial situation of many of these schools and school districts, however, is frequently as poor as that of urban schools. Education in these districts is adversely affected by sparse distribution of people over relatively large areas, small district size or, alternatively, incredibly large districts spread out over large spaces, isolation that constrains transportation and communication, and poverty that affects one in four children in rural areas—the comparable figure for the nation as a whole is one in five (*Dwight D. Eisenhower Mathematics and Science Education Newsletter,* 1993). Rural schools are not all cut from the same mold. In states with small populations and only a few urban areas, rural schools typically are small. In larger states with denser populations, rural school districts may have thousands of students. A school may be classified as *rural* on the basis of geography, the self-definitions of the people involved, or other criteria (Prather & Oliver, 1991).

On paper, rural schools often appear to be cheaper to operate than urban schools because they have lower costs for items like teachers' salaries. The costs of hiring teachers with the highest qualifications, however, are actually greater in rural areas than they are in urban districts (Sherman, 1992). Many well-trained teachers prefer suburbs and small cities to rural areas because of educational opportunities, fear of social isolation, work opportunities for spouses, or better salaries. While people may differ on the advantages for students of having a teacher who has taught for many years, the fact is that only one rural teacher out of five had taught for more than 20 years in 1982, the latest date for which this information is available. In city schools one in three had this level of experience and one in four did in the suburbs. Urban and suburban teachers were four times more likely to have degrees past the bachelor's level than were rural teachers (Sherman, 1992).

Rural local governments may have lower revenue bases available for spending on schools than do suburban and urban governments. In 1989 per capita incomes in rural areas were one-fifth lower than incomes in urban areas. Many rural governments worsen this situation by offering lower tax rates in an attempt to attract industry to their communities. These factors combine to decrease spending for each student in rural areas to 10 percent less than the comparable spending in metropolitan areas (Sherman, 1992).

These financial inequities combine to make it difficult for many students in rural schools to compete academically with students from school districts that have greater tax bases. The U. S. emphasis on the local tax base as the fiscal support for school districts results in wide differences in spending and intense local attachments to schools. Localist emotions about schools sometimes hinder consolidation and other methods for cutting administrative costs. The ideals of local control and community independence may result in less-than-standard schooling for children in rural districts in many states (Harp, 1993).

Can Money Solve Education Problems?

Research in the late 1970s and 1980s found that the money a school district spent had little effect on educational results. A re-analysis of the data in that original research casts doubt on this finding and raises again the question of whether money spent affects student performance.

In a series of articles and books that began to appear in 1972, Eric A. Hanushek found that any positive relation between educational achievement and expenditure disappeared when family background was controlled for. Other factors that he identified as affecting educational results were characteristics of students in the school, curriculum, teachers, and instructional methods. Hanushek felt that if school funding were to be increased "within the current institutional structure" the increases would be "dissipated on reduced class size or indiscriminate raises in teacher salaries" (Hanushek, 1989, p. 50). Eventually increases in costs would outrun increases in student performance.

State and federal policy makers have cited Hanushek's research and line of reasoning while trying to get more out of schools without spending more money. A recent re-analysis of Hanushek's work, however, has led researchers connected with the University of Chicago to question his results. Using data from the same studies Hanushek used, but applying different methods, these researchers found no confirmation of the idea that money does not affect educational outcomes. While money may not answer all of the problems of schools, "the question of whether more resources are needed to produce real improvement in our nation's schools can no longer be ignored. Relying on the data most often used to deny that resources are related to achievement, we find that money *does* matter after all" (Hedges, Laine, & Greenwald, 1994, p. 13).

Issues Involved in Solving Fiscal Inequities

If schools are to provide equal access to good education, merely reallocating existing funds probably will not be adequate to reform science and mathematics education. Reformed science and mathematics education will be expensive, and new resources must be found for them.

Reallocating funds from advantaged schools to disadvantaged schools, whether in the cities or the countryside, may not be a sufficient answer to fiscal inequities. The Rand researchers suggest that educational resources in general should be built up. They further propose that allocation policies should be shaped so that new resources go to disadvantaged schools first. Some of these increased resources, they suggest, might come from alliances of business and education (Oakes, 1990b).

As of 1990 federal money spent directly on mathematics and science education made up only 4 percent of the federal K-12 budget and 0.25 percent of all national school revenues combined (Branscomb, 1992). Karen Seashore Louis and Matthew B. Miles have found that implementing serious change in an urban high school usually involves an investment of $50,000 to $100,000 a year. Some schools spend significantly more and have little to show for it (cited in Fullan & Miles, 1992). For reform to be successful, support for it must be sustained over time, responsive to local needs, and "focused on building local capacity" (Fullan & Miles, 1992, p. 750). Administrators who are committed to reform often find that they must invent ways to fund their ideas by reworking existing resources and going outside usual sources. No matter how obtained, extra funding is almost always a necessity for successful reform.

CHAPTER 2.4 Teacher Expectations and Behaviors

Teachers remain at the core of equity issues. Teacher expectations and behaviors are a major factor affecting equity in U. S. schools. Teacher perceptions of students can be colored by cultural expectations, stereotypes, and inaccurate knowledge gleaned from previous experience. These perceptions and the ways in which teachers express and act upon them can influence student learning.

Teachers' "Ideal Student"

Teachers often have a white middle-class student's behaviors and goals as their ideal of a good student. This ideal can make the classroom inhospitable to minority students and interfere with learning.

In *The Imperial Middle: Why Americans Can't Think Straight about Class* (1990), Benjamin DeMott says that public school teachers have an "ideal" student in their minds, and that student is middle-class and upper-class in behavior, goals, and speech (quoted by Holt, 1991–1992, p. 18). For most teachers that ideal student is also likely to be white. In national data, when socio-economic background and class rank in high school are controlled for, African-American students still do less well in their college grades than do white students. Uri Treisman, a mathematician at The University of Texas at Austin, describes this fact as a measure of "institutional inhospitality" at the college and university level (quoted in Gibbons, 1992b, p. 1194). The same inhospitality seems to exist in elementary and secondary schools, as well. As early as preschool the attitudes of teachers both toward the students they teach and toward the subject matter they are expected to convey may create institutional hospitality. Most teachers in this country are still white, female, and middle class; this fact may undergird the creation and continuation of the expectations and fears of many teachers.

Citing the work of Jacqueline J. Irvine, Antoine M. Garibaldi suggests that students' success or failure in the classroom may be strongly influenced by "teachers' beliefs, attitudes, behaviors, and perceptions." These factors in turn influence "the level and type of communication and classroom interaction, the quality and rigor of instruction and the affect that they show toward their students" which in turn strongly influence assessment and a student's classroom success (Garibaldi, 1992, p. 31).

Teachers' Fears and Expectations

Elementary school teachers often feel unprepared to teach science and mathematics and convey their discomfort to students. At all levels, teachers' expectations of students' abilities and interests in science and mathematics can shape the quality and quantity of learning in the classroom.

Many elementary school teachers do not see themselves as competent to teach science and mathematics because they have not been professionally trained in the subjects. They become anxious about teaching any subject in which they feel poorly prepared (Easley, 1990). These feelings cause them to avoid science teaching, to allow "science" to deteriorate into a period for fun, or to become overbearing and authoritarian in their teaching style (Trumbull, 1990). In such a setting students with little or no out-of-school informal instruction in science and mathematics, frequently true of minority and female students, begin to develop disadvantages in relation to other students, usually white and male, who tend to have more out-of-class experience in learning the subjects.

Teachers may expect little from females or from students from minority groups. They may assume, for example, that children who have not yet mastered English cannot be taught mathematics or science subjects (Gibbons, 1992a). If a student does not speak English, speaks English in a nonstandard way, or comes from a culture with different customs—such as those regarding eye contact, for example—a teacher may see that student as less capable or less receptive (Garibaldi, 1992; Irvine, 1992). C. H. Persell (1977) found that teachers interact differently with students for whom they have higher expectations. For these students they offer more praise for correct answers and less criticism for incorrect answers (Brophy & Good, 1974).

Teacher expectations can have two important effects on teacher behavior: They can affect the amount of material taught to a class or a student and they can affect the types of interactions between teacher and student (Oakes, 1990a). Teacher expectations of a student may be formed by the class he or she is in. If a student is in a low-track class, his or her teacher may expect less than the teacher would expect of a student in a higher-track class. Since students from poor, minority, or non-English-speaking households tend to be in lower-track classes, teachers may form attitudes toward students from these groups that have little or no relation to actual abilities (Oakes, 1990a).

Most teachers accept, at least on the surface, the idea that each student is different and that the teacher must individualize classroom tasks to meet the different needs of the students. While this attitude may be laudatory, McDiarmid (1991) notes that it can allow the teacher to give students assignments that fit a stereotyped idea of abilities.

Individualized instruction must be based on perceptions of actual individuals rather than on stereotypes. Some teachers seem to have "little awareness that differentiating tasks and assigning them on the basis of students' perceived ability may result in unequal opportunities to learn the subject matter." (McDiarmid, 1991, p. 267). Teachers must understand how their cultural assumptions affect their own perceptions of students' abilities.

Teachers must also understand the real needs of their individual students and must be able to relate those needs to the classroom content. "An erudite portrayal of an important concept has no value if students can't understand it, but neither does an engaging portrayal that is inaccurate" (Kennedy, 1991a, p. 276). In a 1986 paper, Cummins identified two teaching models: the transmission and the reciprocal interaction models. Cummins describes the transmission model, in which the teacher initiates and controls interaction, as emphasizing drill, workbook exercises, and other highly structured work. The reciprocal interaction model is characterized by dialogue and teacher facilitation, rather than control, of the student. Cummins claims that the latter model is more conducive to success for poor and minority students and for females (Cummins, 1986). Teacher expectations affect the teaching style adopted in relation to different students and may diminish the learning opportunities of students perceived as less willing or able to learn. Little research, however, has been done on the effect of teacher expectations on the performances of poor and minority students. Much more research has been done on the effect of teacher expectations on the learning experiences of female students.

Teachers' expectations in science and mathematics are an important shaping force for female students of all races and socio-economic backgrounds. Research has shown that teachers, female and male, accept cultural assumptions that girls are not interested in science. In all subjects teachers often have lower expectations for girls than they do for boys. They tend to make eye contact with boys more frequently than they do with girls and in general they show more attention to boys. In their comments about boys' work teachers often focus on the ideas and concepts contained in the work, while their comments about girls' work often center on the appearance of the work. In class teachers tend to ask boys more analytical questions and to ask girls more factual, procedural questions (American Association of University Women, 1992).

Teachers could be a more important influence on girls' interest in science than on boys' interest. Girls express more negative attitudes toward science than do boys. Cultural assumptions result in most girls having less out-of-school informal instruction that relates to science concepts than boys do. As a consequence, girls' science knowledge tends to be school based, while boys' tends to be based on a broader range of experience. Hands-on science teaching in the school, thus, will provide girls with a broader base of experience than they already have and will give them "a shared base of experience" with boys (*Education Daily*, 10 June 1993).

Around seventh grade many young women begin to underestimate their abilities in mathematics and science, even when they are performing comparably to males on standardized tests. During this same time young women also begin to take fewer science and mathematics courses than do young men; this trend accelerates in high school. By the time they graduate from high school, careers in mathematics and science are ruled out for these young women because they lack the necessary preparation (Alper, 1993).

Teachers may need to make extra efforts to ensure that girls have opportunities to perform hands-on work in the classroom. Recent research has found that in science classes boys tend to operate equipment and perform experiments while girls tend to record data and write reports (Jones & Wheatly, 1988). Teachers may need to intervene directly in small group exploratory work if female students are actually going to be able to perform hands-on work.

Teachers' interactions with students play a large part in developing individual students' ideas of personal competence in science and mathematics. In one research study teachers gave fourth-grade boys more wait time after a question than they gave to girls (Gore & Roumagoux, 1983). Other work on wait time has indicated that the quality and scope of students' answers improve with increased wait time. If boys are being given more wait time than girls, the quality of their work would tend to improve more than would the quality of girls' work.

In observations of mathematics classes in third, sixth, seventh, and tenth grades, Gilah C. Leder, an Australian researcher, found no evidence of consistent bias in wait time for students of either gender. She observed, however, that boys at each grade level interacted more with teachers than girls did. Boys had more exchanges of all types, including work-related and teacher-initiated. Boys also initiated more interactions with teachers than girls did and asked more cognitive questions. In third grade for every six interactions teachers had with boys they had somewhat fewer than five for girls. By tenth grade teachers had five interactions with boys for every four with girls. Leder believes that the cumulative effects of the consistent differences in teachers' behaviors will continue to contribute to and reinforce students' perceptions of themselves as learners of mathematics. In earlier research Leder had found that perceived student ability was an important variable in the amount of time teachers spend with students (Leder, 1990).

Quantity is not the only variable in teacher-student interactions, however; the quality of interaction is also different. Teachers tend to give both more criticism and more encouragement to male students. Feedback to female students tends to be neutral and to imply that females are less independent than males and less likely to need the knowledge that they are supposed to be acquiring (Sadker & Sadker, 1986). Myra Sadker and David Sadker studied more than 100 students in fourth, sixth, and eighth grades for three years. They classified four types of teacher comments: praise, acceptance, remediation, and criticism. Boys received more of all four types of comments but were also much more likely to be the objects of praise, criticism, and remediation—the three most useful kinds of comments. In the Sadkers' research when a teacher took the time to evaluate a specific student's work that student was more likely to be male than female (Sadker & Sadker, 1984).

Teacher Education

Observers differ on whether teacher-training courses on multiculturalism actually change behaviors and attitudes of teachers or future teachers. Reading and lecture courses seem especially ineffective in changing behaviors and attitudes. Teaching to diverse students is not amenable to formulaic approaches, and teachers must be prepared to manage their classrooms so that all students can learn. Teachers in mathematics and science, however, are often poorly prepared to teach their subjects. This lack of preparation may have differential effects for poor and minority students.

Teacher education and preparation may do little to help teachers alter their behaviors and expectations (Garibaldi, 1992; McDiarmid, 1990; Schuhmann, 1992). As the Holmes Group has pointed out, "an enormous disjunction" exists "between the bland climate of teacher education and the agonizing problems of schools serving poor children" (Holmes Group, 1990, p. 34). Most teacher education still neglects issues of equity; those preservice classes that do cover these issues appear to do so poorly (Zimpher & Ashburn, 1992; Howie & Zimpher, 1989).

Teachers need to learn many things about culture—both their own and other cultures— before they enter the classroom. They need to know that no culture is static and that individual families make their own adaptations to both their own culture and "mainstream" culture. Teachers need to realize that within a large group many variations may exist— that, for example, "Hispanic" culture includes Mexican, Puerto Rican, Cuban Dominican, Costa Rican, and other groups. They need to realize that race and ethnicity do not equate with culture, that there is, for example, no homogeneous African-American culture.

Teacher education regarding equity usually is labeled as *multicultural* or aimed at *diversity*. These two terms need to be investigated. Although variations of the terms *multicultural* and *diversity* appear with ever-increasing frequency in discussions of U. S. education, few writers have defined them. Kenneth Zeichner (1993, p. 1) consciously stops his narrative to define the word *diversity*:

> my use of the terms *diversity* and *diverse learners* in this report focuses primarily on differences related to social class, ethnicity, culture and language. I am specifically concerned about those situations where (a) white, monolingual teachers have different ethnic, cultural and/or language backgrounds than their students and (b) the students are those with whom teachers typically do not succeed (i. e., they are mainly poor students of color).

Others have used *diversity* to mean other things: attracting nonwhites and speakers of languages other than English into teaching, teaching a multicultural curriculum in all classrooms, acknowledging diverse capacities for learning, valuing different approaches to teaching (Zimpher & Ashburn, 1992).

Multiculturalism is a different issue from diversity. Writing from an Australian perspective, Kalantzis, Cope, Noble and Poynting (1990) offer a description many would find appropriate in the U. S. context. They include in the idea of multiculturalism incorporating rather than excluding students' cultural and linguistic backgrounds, involving the community in the running of the school, involving children in the active making of their own knowledge, positively assessing students on the bases of their "development in relationship to a task," and using collaborative decision making in running the school (p. 217).

On a theoretical level, Peter McLaren, of the UCLA Graduate School of Education, has said that multicultural education must "attend...to the specificity (in terms of race, class, gender, sexual orientation, etc.) of difference...yet at the same time address...the commonalty of diverse Others" (McLaren, 1994, p. 201). Too often multicultural education has been a form of accommodation rather than of participation; distinctive viewpoints are not honored or made central to education but are merely tapped into in order to appeal to perceptions of interests (Green, 1978). Genuine multicultural education does not merely include references to heroes of other cultures or have days when different types of food are sampled. As Trinh T. Minh-ha (1991, p. 232) has put it

> To make a claim for multi-culturalism is not...to suggest the juxtaposition of several cultures whose frontiers remain intact, nor is it to subscribe to a bland "melting-pot" type of attitude that would level all differences. It lies instead in the intercultural acceptance of risks, unexpected detours, and complexities of relation....

On a more practical note, Claudia Zaslavsky (1993), writing from her experience in a school district north of New York City, holds that "multicultural education...should include the contributions of all peoples as well as concern for their problems and difficulties." Zaslavsky believes that multicultural education must deal with "the factors in our society that prevent the effective participation of all citizens in a democratic society" (p. 45).

Most commonly, colleges of education approach multiculturalism by offering various courses and some form of field experience within the preservice preparation. Sometimes they deal with diversity or multicultural issues as subtopics or add-ons in other education courses or field experiences (Zeichner, 1993). Some studies indicate that merely taking courses in multiculturalism and diversity does not incline future teachers to reject stereotypes; in fact focusing attention on gender and cultural differences may reinforce previous assumptions. In G. Williamson McDiarmid's (1990) evaluations of multicultural training, the training made no difference in teachers' rejection or acceptance of stereotypes. Cazden and Mehan (1989) believe that exposing preservice teachers to information about different cultural groups is "both impossible and potentially dangerous....It is impossible because there may be too many cultures represented in the classroom; it is dangerous because limited knowledge can lead to stereotypes that impede knowledge" (p. 47)

Since other studies show the opposite, the research in this area is not definitive. Burstein and Cabello (1989) studied an experimental program designed to train education students to teach culturally diverse students who had learning handicaps. They found that most teachers who went through the training and also worked directly with the student population were more likely to attribute the students' performance to cultural differences, rather than presumed deficiencies.

McDiarmid's research (1990) suggests that in the classes he studied the problem with training was reliance on the lecture method. Multicultural training might be more successful, he holds, if the teachers being trained interact with each other rather than listening to presenters. The Holmes Group believes that most mandated courses on multiculturalism have little or no effect on teaching because these courses "lack coherence, intellectual rigor, and opportunities for follow-up and reflection on practice" (Holmes Group, 1990, p. 37). Offering separate multiculturalism or diversity classes to address equity issues relieves faculty who are not teaching such courses of the responsibility of making their own courses more inclusive (Gollnick, 1992, p. 68).

Integration of diversity and equity issues into all of a potential teacher's educational and professional experiences seems to be a more fruitful approach to altering teacher expectations and behavior than are isolated classes. In Texas the Minority Mathematics and Science Education Cooperative (MMSEC), sponsored by the Texas Higher Education Coordinating Board (THECB), offers teacher enhancement programs for elementary school teachers. The program integrates the learning of mathematics or science concepts with affective learning designed to increase knowledge of the diverse cultural characteristics of the student population (THECB, n.d.).

Carl A. Grant (1991) has pointed out that when teachers do ask for help in understanding students from other cultures they are generally assuming some form of a deficit in those students, and they are usually looking for "recipes" to use in teaching students they believe to be significantly different in cognitive or other ways from other students. Deficit—or deprivation—theories, which reached their peak of popularity in teacher education during the 1960s and 1970s, assume that some students lack important traits or that their cultures deny them important skills or attitudes. "The cultural deprivation theories were based on the assumption that because ethnic minority and lower-class students do not exhibit in school the cultural characteristics of middle-class youngsters, they were deprived of a valid culture" (Garcia, 1991, p. 67). The presumption, then, was that students needed to be taught skills and attitudes that would make them more "American." As Ralph Ellison noted in 1966, deficit theories imply that "the Negro culture is not also American, assumes that Negroes should desire nothing better than what Whites consider highest" (quoted in Grant, 1991, p. 238).

Grant believes that teachers do not need recipes or formulas for teaching students from diverse backgrounds; instead they need an understanding of the historical and ideological points of view that shape school policies and practices. Teachers need to know and understand their own lives and the processes by which they have absorbed their own cultures. "Cultural superiority and elitism on the part of whites have become so thoroughly institutionalized into the country's social fabric that many people, including educators, fail to recognize some of the many guises it assumes" (Grant, 1991, p. 239). What use is it to give teachers information about the culture of their students if teachers then use that information to reinforce ideas of their students as incapable of learning?

Many teachers never substantively converse with students from other cultures to find out about their life experiences and the relation of their cultures to the school. "The education profession in general is similar to society in institutionalizing racism....it is necessary for teachers to analyze their biographies in order to determine how the enculturation process influenced them about race, class, and gender issues in regard to other cultures" (Grant, 1991, p. 247). Teachers must understand themselves and their students as individuals, Grant holds, before they can use any abstract information about the students' cultures. As bell hooks has put it, "studying 'the other' is not the goal, the goal is learning about some aspect of who you are" (hooks & West, 1991, p. 33). The hope is that teachers who understand themselves and their own cultures will experience a transformation in their self-knowledge and that this transformation will revitalize respect and caring and create a new ability to understand students and their cultures.

Geneva Gay (1993) envisions revamping teacher education so that teachers become cultural brokers who understand different cultures, can interpret symbols from one culture to another, can mediate between cultures, and can build links between cultures to ease instruction. In her scheme teachers would in essence become "bicultural actors" who acquire cultural knowledge, facilitate change, and translate "cultural knowledge into pedagogical strategies" (p. 293). To reach this proficiency future teachers would have to acquire information about specific ethnic and cultural groups but would also have to understand the "pedagogical implications of these cultural characteristics" (p. 293) and develop a pluralistic philosophy of teaching. Their knowledge acquisition would have to include first-hand participation in cultural communities and a "field-based practicum in which students spend concentrated periods of time in culturally pluralistic school sites"(p. 294). None of this change, according to Gay, can be left to individual teacher's good will and desire for change. "Desire alone" will not bring about change without "a realistic and reliable operational framework" and accompanying changes in organizational behavior (p. 295). "Nor can participation in multicultural learning experiences be left to choice and chance—it must be mandatory and carefully planned" (p. 297).

According to Grant, teachers need to know the difference between "primary and secondary cultural differences" if they are to offer a successful learning experience to students from cultures other than their own. If information about students' cultures is to be offered to teachers, they must also be made aware that research on culture is inconclusive, contentious, and often contradictory (Grant, 1991, p. 251).

College courses can attempt to teach future teachers how to educate students with respect, but they cannot alter the systemic inequities of the schools and the larger society. McCarthy (1990) has argued that, when the objective of education becomes improving contacts between school and home so that individual students may improve their test scores, the upward mobility of one person is made more important than systemic change. Villegas (1989) has also argued that the idea that teachers can mend some incompatibility between home and school and, thus, help improve students' performances ignores the social, economic, and political problems reflected in the schools. Haberman (1991) believes that diversity classes taught in colleges of education will not make white monolingual students effective teachers of students from other backgrounds. Teacher education classes cannot produce the kinds of complex changes needed to create successful teachers of students from minority groups.

Many teachers of science and mathematics, however, are not even adequately prepared in their subjects. In 1990 Brown, Cooney, and Jones found that "preservice elementary teachers do not possess a level of mathematical understanding that is necessary to teach elementary school mathematics as recommended in various proclamations from professional organizations such as NCTM" (p. 643).

The situation is no better in science. Elementary school teachers who graduate from college are "in immediate need of substantial remediation" in science subjects (Weiss, 1988, p. 113). The content of college course work is often not appropriate for those who will be teaching young children (Weiss, 1988). Little time is spent, for example, on material for hands-on teaching. Teachers of middle school and high school classes have frequently taken more science classes, but they are also often assigned to teach in science areas outside of their specialties (biology teachers teaching physics, for example). These problems are magnified in schools that serve poor and minority students. In these schools resources are more limited and teachers are more likely to be inexperienced, underschooled, and teaching out-of-field.

Teachers' Culture

A conservative teachers' culture—formed by a hidden pedagogy, belief in individualism, bureaucracy, and professional preparation—makes reform difficult. In order to succeed reform must fulfill certain criteria for teachers: It must be instrumental, congruent, and cost-effective.

While each school—and often even subgroups of teachers within schools—has its own culture (Fieman-Nemser & Floden, 1986), Lynn Davis (1990) has summarized the work of various researchers who have identified an international teachers' culture. "Traditional authoritarian schools tend to have a certain sameness about them, no matter where they are located" (p. 135). This culture is conservative and is reinforced by "certain uniform features of teaching": a "hidden pedagogy," teachers' belief in individualism, the bureaucracy of schools, and professional preparation (p. 136).

The hidden pedagogy, as identified by Davis, is made up of teachers' strategies for dealing with the limits of time and space, teacher isolation in the classroom, and the geography of schools. Almost everywhere teachers work behind closed doors and activities, such as grading papers and preparing lessons, that could be shared among teachers are instead solitary.

The belief in individual effort that seems to be shared by almost all teachers leads them to cultivate the abilities of individual students. Belief in individual effort can make one blind to social, economic, cultural, and political contexts. Teachers may see only a failure of the particular student to "work hard" or "apply himself," rather than looking for underlying contexts that structure the student's approach to schoolwork (Davis, 1990). This inability to see contexts may have important effects on teachers' views of equity.

Teachers seldom believe that they are "active negotiators" regarding their work conditions. While teachers may be isolated and possess some autonomy within their classrooms, they feel that administration constrains their working conditions. A belief that initiatives and orders come from the top down is reinforced in the classroom, where the teacher becomes the "top" and the student the "down." Davis believes the feeling that school bureaucracy deprives teachers of control over their work reinforces their conservatism.

Teachers everywhere seem to share a "practicality ethic" (Davis, 1990, p. 137). They construct recipes for transmitting knowledge out of their practical daily experience and common sense. Innovations threaten this recipe. If it is to be used, any change must be viewed by teachers as practical and must meet three criteria: A change will have to be **instrumental**—not based only on a theory or a principle but useful to daily actions. It will have to be **congruent** and fit in with the way the teacher works. Last, teachers must see innovation as **cost-effective** in terms of work involved in making the changes. Reforms to existing science and mathematics curriculum or teaching strategies will be judged by these criteria, whether they are instituted for equity or other reasons (Davis, 1990).

CHAPTER 2.5 *Curriculum*

Teachers often feel constrained by the curriculum expectations of parents, the school district, and state-mandated goals. Curriculum has been a major focus of the most recent education reform movement in the United States. In 1989 the editors of *Scientific Literacy* found "existing scientific curricula socially, culturally, and cognitively outdated" (Hurd, 1989, p. 21). Curriculum must reflect current content knowledge and be relevant to students. So all students have the opportunity to learn economically, intellectually, and socially valuable skills and knowledge, curriculum must accompany instructional approaches appropriate to the learning objectives of individual students and the community (Collins, 1989).

Standardized Tests Drive Curriculum

Despite the fact that they generally do not measure the knowledge that will help students deal with the world of work, standardized tests determine the curriculum of most science and mathematics classrooms because they make for easy accountability.

A study published in 1989 found that most teachers of eighth-grade mathematics made teaching decisions based on the content of the standardized tests their districts administered to students (Romberg, Zarrina, & Williams, 1989). Since accountability not only of the teacher but also of the school and district is often measured by students' scores on these tests—prepared by outside experts at the national or state level—curriculum emphasizes preparing students to pass these examinations. Under such a science and mathematics curriculum the view is that "learning can be made efficient" and must be "carefully structured [by] prepared materials with clearly stated learning goals and specific objectives." In this view of education, "objective tests are designed to measure the achievement of the prespecified goals and objectives" (Trumbull, 1990, p. 11).

The result is a "rationalistic and technocratic" (p. 11) curriculum that allows teachers and administrators to describe clearly what is supposed to happen in the classroom. Another result is that both students and teachers are frequently bored by a deadening lock-step approach to the subjects. Such a curriculum lingers on "discrete topics" that are rarely related to each other, out-of-context facts, and a "disembodied vocabulary" with little meaning outside the classroom (Loucks-Horsley et al., 1990, p. 14). Such a curriculum gives science and mathematics little or no relation to students' present or future lives. The subjects are perceived only as "magic keys" that allow one through the gate of testing but are then discarded when one reaches the goal—scoring well.

Teachers may change their instruction and testing to conform with a standardized test, but "analysis indicates the test is not aligned with the future needs of students" (Chambers, 1993, p. 80). Neither are tests aligned with the present needs of many students. Stan Karp (1990, p. 260) has called this process "educational triage" since students who perform least well on the tests are sacrificed and their specific needs are ignored so more time may be spent pulling up the marginal scores of students who could exceed the numerical indicator of success. While the goals of mathematics teaching, as articulated by the National Council of Teachers of Mathematics (NCTM), are to include higher order thinking and a knowledge of topics other than arithmetic (that is, probability, measurement, algebra), Romberg and Wilson (1992) found that in six widely used standardized tests 11 percent of the mathematics items were conceptual and 89 percent procedural. Fully 71 percent of the questions dealt with arithmetic.

More than 70 percent of Americans believe that standardized tests should be used to compare student achievement in different districts and 85 percent believe that they should be used to find out where students need extra help. Standardized tests, however, do not reflect a curriculum that helps students deal with the needs of the larger world and the workplace (Elam, Rose, & Gallup, 1992). The tests also are of little help to teachers in measuring students' progress. Depending on the individual school and district and relevant state laws, few teachers have data available to them that chart the changes in a particular student's work. Most data from standardized tests compare classes that no longer exist (they disbanded last year) in one school with classes that no longer exist in another school (Karp, 1990). What standardized tests do well is "measure teachers' 'productivity' [and] control what they teach" (Rosen, 1990, p. 253).

Approaching a Fair Curriculum

Curriculum can be made relevant to daily life without lowering standards. A fair curriculum will affirm variation, be inclusive, be accurate, value individual and group worth, balance perspectives, and integrate experiences, needs, and interests of diverse groups. Even major reform efforts seem to fall short of these criteria.

One approach to curriculum reform is to focus instructional activities on societal issues and concerns that affect students' daily lives (R. Tobias, 1992). Another is to develop higher-order thinking skills and problem-solving abilities. (These two approaches are not mutually exclusive.) In the compilation, *Nurturing At-Risk Youth in Math and Science* (Tobias, 1992), the various authors point out that low-track classes focus heavily on the relevance of science to daily life but only emphasize computational skills in mathematics. The emphasis on real-life skills in low-track classes is usually strictly vocational and designed not to educate or awaken students but to train future workers to fill jobs "society does not esteem" (Rose, 1990, p. 28). In contrast, high-track classes are supposed to develop inquiry and laboratory skills and encourage problem solving. Dr. Melvin Webb, director of the Comprehensive Resource Center for Minorities at Clark-Atlanta University, claims he "can determine the number of minority students in a given school by counting the number of 'funny math' courses offered and multiplying by 35" (quoted in Long & Conrad, 1992). Such classes, he holds, serve no one, least of all the minority and female youth they are intended to serve because, in his view, such classes offer reduced and sometimes meaningless content and lower standards.

Those who favor altering science and mathematics curriculum to make it more relevant to a student's daily life argue that such an approach does not have to lower standards. Rather, such alterations can be carried out in ways that support increased interest and greater success in mathematics and science for the students concerned and, at the same time, enable them to deal with more advanced material (Clewellet al., 1992; Dilworth, 1992). Those who wish to change curricula will, however, need guidelines to ensure that changes reflect the make-up of the student body.

Gretchen Wilbur, a curriculum researcher, has identified six attributes of a gender-fair curriculum: It **affirms variation** by showing similarities and differences among and within groups, is **inclusive** by allowing males and females to find positive messages about themselves, is **accurate** in the information and data it presents, is **affirmative** in acknowledging and valuing individual and group worth, is representative in **balancing perspectives**, and is **integrated** in presenting the experiences, needs, and interests of various groups. Wilbur can name no major curriculum reform attempt to date that fulfills all six of these criteria. She believes that the NCTM *Standards* fulfill three—variation, accuracy, and representation—but do not explicitly cover the other three. She also found that, while Project 2061 of the American Association for the Advancement of Science describes equity as the center of curriculum reform, its materials are still focused on European scientific history and on "great men" (AAUW, 1992, p. 64).

While Wilbur's six criteria have relevance to more than gender equity, the literature surveyed reveals no proposals for explicit criteria for a culture-fair curriculum, although many proposals are at least implicitly aimed at a curriculum that is equitable across cultures. While not defining "at risk," the National Center for Improving Science Education (NCISE) has suggested a curriculum designed to appeal especially to at-risk students. The center believes that such a curriculum will appeal to all children, not just those who are labeled at risk. "All children have a low tolerance for uninteresting activities that they see no purpose for. Much of the mind-numbing drill imposed on at-risk children today falls into that category" (NCISE, 1989, p. 45).

NCISE recommends that curriculum

- emphasize students' **immediate environment** to relate to their daily lives,
- use biography and history to show that science is **not the "exclusive province of white males** ,"
- use such **out-of-school resources** as zoos, hospitals and museums.
- build on **cooperative learning**
- use instruction based on **experience and inquiry and multicultural views** of the natural world.

Less is More—Sometimes

Those involved in the reform of science and mathematics education advocate studying fewer topics in greater depth with a focus on the links between facts and concepts. This "less is more" approach is not to be confused with stripped-down narrow curricula that are often foisted on rural students and other underrepresented groups.

Many researchers and reformers believe that the interests of all students—minority, white, male, female, high-track, low-track, rural, urban, suburban—will be best served by a curriculum that covers fewer topics in greater depth rather than many subjects superficially. Advocates of this "less is more" concept believe that it allows students to develop a deeper understanding of science and mathematics. "If students learn a few concepts in depth, then they can apply them to new situations or problems" (National Science Teachers Association, 1992, pp. 14-15). Students are also more interested when they see how a subject relates to their daily lives and to "larger human concerns" (p. 15). Advocates believe that a less-is-more curriculum gives students time to "test their ideas against those of other students and to accumulate evidence" about their emerging understanding (NCISE, 1989, p. 4). Such a curriculum, they point out, eliminates memorization of a growing number of facts and promotes a more thorough understanding of concepts.

Less is more is not the same as the spare "dumbing-down" curriculum that is often foisted on students labeled at-risk or forced onto the low track. In the less-is-more concept, students engage in fewer topics but actually learn more because what they learn is organized around "major organizing concepts" (NCISE, 1989, p. 10). Advocates of a less-is-more curriculum envision students learning a rich and varied content that prepares them for more advanced study. Traditionally, schools emphasize the need for students to acquire a large mass of facts before they can understand abstract generalizations. When too many unconnected facts are presented, however, students fail to "develop the mental structures that make the factual information memorable and useful" (NCISE, 1989, pp. 4-5). With fewer topics, students can absorb facts and make them meaningful. With less-is-more curriculum designers face the problem of choosing topics that can contribute to students' understanding of the organizing concepts (NCISE, 1989).

Rural and low-track students are often presented a curriculum that offers no emphasis on concepts or developing understanding, yet is narrow and spare (Sherman, 1992). In rural schools individual teachers are often called on to teach more diverse subject areas than their suburban colleagues do. Even with teachers doing double duty, however, course offerings may be limited in rural schools. In the early 1980s one-third of rural schools offered calculus, compared to one-half of urban schools and two-thirds of suburban schools. More rural schools offered trigonometry, about three-quarters, but this percentage was still lower than that for city and suburban schools (Sherman, 1992).

CHAPTER 2.6 Instructional Approaches

If students are to be meaningfully engaged in science and mathematics, most teachers will have to adopt different instructional approaches. The old lecture-dominated mode of passing on science facts and mathematical formulas does not hold the attention of many students and especially not the attention of those who feel that they are "unscientific" or "unmathematical." Changing instructional methods for all students is an indirect approach to equity issues, but research suggests that such changes will benefit poor, minority, female and other underrepresented groups, while also engaging the attention of traditionally high achievers in science and mathematics.

Learning Disembodied Science and Mathematics

Memorization of textbook facts detracts from the excitement of science and mathematics. Connecting key concepts in appropriate sequences will help make subject material more meaningful for all students.

Typical U. S. science programs discourage meaningful learning by emphasizing mastery of separate facts over understanding. Elementary school children are seldom taught the content of science; rather they are drilled in discrete facts and "disembodied skills" (NCISE, 1989, p. 2). Students are given "textbook science" that offers them neither time nor experience to connect facts with the natural world that they know or to make sense of the principles that underlie the facts. Pointless memorization of facts, formulas, and vocabulary words turns elementary school science into an ordeal for most students. When these children enter middle and secondary school they are expected to apply the facts and terms they should have learned to new concepts and to "memorize as many new terms as are required in foreign language classes" (NCISE, 1989, p. 2). At this stage the majority of U. S. students from all social classes and backgrounds, both male and female, decide that science is boring; even most of those who had been interested in science turn away at this point. Those who do persist are generally students who have always expected to succeed.

The same process occurs in mathematics. Traditional teaching of mathematics has emphasized "practice in manipulating expressions and practicing algorithms as a precursor to solving problems" (NCTM, 1989, p. 9). Students work with rows and pages of abstract meaningless numbers that have no context or bearing on the real world: "day after day of drill sheets and repetitive activities in the elementary and junior high school, algebra taught as a foreign language, geometry taught without connections to any objects in the physical world" (Usiskin, 1993, p. 15). In most schools, students spend a good portion of their mathematics time reviewing what they already know from the previous year. It is little wonder that most find the subject boring.

The traditional flow of secondary school courses compounds this trend and further separates science and mathematics ideas from each other. The pattern is for a high school student to take biology in one year, chemistry in the next, and physics in the senior year. The same trend holds true in mathematics where the classic flow is from algebra to geometry to trigonometry. Moving from one subject to another collecting facts along the way in this classic "layer cake" approach, students seldom make connections between the disciplines, between the facts they were assumed to have learned in successive years, or between science and mathematics and reality.

This emphasis on memorization of isolated facts and formulas discourages learning. "If we want students to learn science, mathematics, and technology well, we must radically reduce the sheer amount of material now being covered. The overstuffed curriculum places a premium on the ability to commit terms, algorithms, and generalizations to short-term memory and impedes the acquisition of understanding" (Project 2061, 1993, pp. xi–xii). Students should experience science and mathematics within the context of the problems and needs of daily life. Rather than a passive process of absorbing information, learning is "guided by the search to answer questions—first at an intuitive, empirical level; then by generalizing; and finally by justifying (proving)" (NCTM, 1989, p. 10).

The National Science Teachers Association (1992) advocates in *Scope, Sequence and Coordination of Secondary School Science* (SS&C) that teachers present key scientific concepts in appropriate sequences. As students work with these concepts over the years they should be able to construct their own scientific understanding and skills in a variety of situations and experiences (NCISE, 1989). Their scientific understanding will be deeper and more amenable to learning advanced concepts than it was under the old rote learning system. Examples of such broad concepts include organization (or orderliness), cause and effect, systems, scale, models, change, structure and function, variation, and diversity (NCISE, 1989). The authors of *Benchmarks for Scientific Literacy* agree with this approach: "The common core of learning in science, mathematics, and technology should center on science literacy, not on an understanding of each of the separate disciplines" (Project 2061, 1993, p. xii).

The NCTM has also organized its standards around interrelated mathematical concepts and procedures: problem solving, communication, reasoning, and mathematical connections. In NCTM's vision, the curriculum must "include deliberate attempts, through specific instructional activities, to connect ideas and procedures both among different mathematical topics and with other content areas" (NCTM, 1989, p. 11).

The presentation of major scientific and mathematical concepts must be coordinated within each discipline and between disciplines. Over seven years or so students should encounter successively more abstract expressions of concepts, principles, and laws. Elementary school students, for example, might learn about scale by drawing objects in actual size and comparing their drawings to small-scale representations, while older students might approach the same concept by using a microscope or a telescope and describing their magnification effects. Teachers should cover fundamental science concepts over a course of years rather than weeks or days as they do now. They should return to the concepts and develop them to a higher level of understanding and should cover the same concepts in different disciplines. Change, for example, can be covered in earth sciences as erosion and other geological processes and in health as part of puberty or the menstrual cycle. Students will be helped in forming concepts by seeing them presented in different contexts (NSTA, 1992). Lee V. Stiff (1993, p. 4) believes this approach will be fruitful for students who have traditionally been left out of mathematical and scientific success because

> a more relevant and comprehensive curriculum offers greater opportunities for all students to engage in meaningful mathematics. Many of the skills and concepts that receive greater emphasis can help teachers and students make mathematical connections and become an effective way to motivate students to study mathematics.

If misunderstood, teaching concepts for depth of understanding can become its own form of "rote manipulation of abstract formalisms" (McKnight et al., 1990, p. 99). If concepts are not embedded within the curriculum in ways that allow them to be expanded and deepened rather than merely revisited, the idea of teaching concepts will degenerate into "a curriculum that goes around in circles" (McKnight et al., 1990, p. 99). Each time a student encounters a concept understanding should be deepened.

SS&C also recommends that science and mathematics instruction not occur within tracked classrooms but within a heterogeneous classroom, where students of different ability levels can "exchange ideas and learn from each other" (NSTA, 1992, p. 15; Rutherford & Ahlgren, 1990). In its presentation of a core curriculum, the NCTM holds that "current practices of prematurely tracking students into either college preparatory sequences or 'general mathematics' sequences on the basis of narrow perceptions of performance or curricular goals" (NCTM, 1992a, p. v) denies many students the necessary breadth and depth of topics. To account for "differentiation in learning outcomes," the core curriculum should blend "core lessons for all students with extended activities that students can complete to different depths and levels of abstraction and formalism" (NCTM, 1992a, p. vii). The teacher then ensures that each child has the opportunity to review his or her understanding of a topic and to be exposed to a range of problem-solving approaches.

Mainstream Teaching or Alternative Methods?

Alternative instruction methods that emphasize understanding and meaning rather than memorization appear to facilitate mastery of skills by all students.

The mainstream teaching practices that embody the existing disjointed approach to teaching have grown out of conventional wisdom regarding teaching. In most classrooms today instruction more closely resembles that of 50 years ago than it does any envisioned by educational reformers (see, for example, Papert, 1993, pp. 1–2). The whole process is teacher centered. Curriculum is supposed to proceed in a linear fashion from simple basics to advanced material in an environment controlled by the teacher. The instructional repertoire concentrates on "teacher explanation and independent seatwork" (U. S. Department of Education, 1993, p. 59). When teachers are unsure of the content, as are many if not most elementary school teachers of science and mathematics, such teacher centeredness can be a recipe for disaster.

Skills are taught in isolation from each other with little or no reference to life outside of the classroom. Instruction focuses on what students are believed to lack—"print awareness, grasp of standard English syntax, a supportive home environment"—and tries to remedy these perceived deficiencies through teaching discrete skills (U. S. Department of Education, 1993, p. 32). Students are grouped by ability and are expected to work on specific tasks. A child who cannot perform within these boundaries is targeted for reteaching in specific skills, sometimes through supplemental instruction. These methods may improve basic skills but they probably hamper learning more advanced skills.

According to the U. S. Department of Education, children from low-income districts who were taught by alternative practices that emphasize meaning and understanding (for example, cooperative learning, use of manipulatives, peer coaching) usually have a greater grasp of advanced skills at the end of the school year than their peers without such exposure. No evidence indicates that alternative practices impede mastery of basic skills for any students, and some evidence suggests that instruction that emphasizes meaning and understanding can actually facilitate mastery of basic skills. Alternative education techniques also appear to increase low-performing students' grasp of advanced skills. When low-achieving and high-achieving students from low-income districts are both exposed to alternative instruction methods, each group strengthens its grasp of advanced skills (U. S. Department of Education, 1993).

Constructivist Learning

Constructivism presumes learning to be an active rather than a passive process. By the time they start school, students have already "constructed" ideas about mathematics and science. By analyzing students' preconceived ideas and helping students to build from those ideas in meaningful ways, teachers can promote learning. Teachers become facilitators of experiential learning rather than transmitters

of knowledge. Since instruction addresses each student's ideas and experiences, constructivist approaches can engage each student in his or her own learning.

Traditional science instruction has been based on two major assumptions about how children learn. Perhaps most important has been the assumption that children are blank slates when they come to school—that they know little or nothing about science and mathematics before the teacher reveals these subjects to them. Working from this assumption, teachers have believed that their courses must begin at the beginning and cover everything. Classroom lecture and extensive text reading have been seen as the most efficient ways to present the most science and mathematics to students. At the end of units and courses massive "objective" tests are used to assess how much students understood—or at least retained. The increasing depth and breadth of scientific and mathematical knowledge, however, has made this approach more difficult, whether or not it has been the most efficient way to engage students in the subjects.

Second, traditional teaching has assumed that each student learned best in his or her own head isolated from other students' ideas and thoughts. Only in laboratory exercises have students been encouraged to collaborate and, even then, working together on actual laboratory reports was discouraged. The task of understanding information is seen as solitary and each student is evaluated individually to see how he or she has performed in comparison with other students. This procedure makes it easier to identify the best and most capable students who can go on to further study. Students assumed to be less capable have been filtered out in this process.

Research into how children actually learn has not substantiated these beliefs. These traditional assumptions are being replaced by what is usually known as "constructivism," which has far-reaching implications for how instruction should be structured, delivered, and assessed.

Constructivism acknowledges that even the youngest child brings his or her own knowledge into the classroom. This knowledge is made up of useful ideas that have value and meaning for the child and is usually attached to ideas about how things work in the natural world. The ideas the student has constructed may be more or less sophisticated but the child uses them to make sense of the world and to construct new meanings and understanding (Driver, Guesne, & Tiberghien, 1991).

Furthermore, students do not easily let go of their preconceived conceptions. If classroom teaching contradicts what they already believe about the world, students may elect other options beside changing their ideas. They may construct ideas that seem to allow for both their own and the school's interpretation. Alternatively, they may compartmentalize their views of the world with one view for school and another view for the outside world both kept separate and co-existing in the student's mind. Unless the teacher realizes that students' ideas do not always change rationally, classroom teaching can actually help students to construct faulty ideas by joining classroom ideas to pre-existing ideas and creating a montage of misunderstood conceptions.

Simply giving a child new information will not refine existing knowledge. The child must have a meaningful and useful context in which to shape the new information. The ideas that the student has formed were not created in a vacuum; they have been formed by the social and cultural life of the student's home and community. Alejandro José Gallard (1993) illustrates this principle with the example of the children of migrant workers. These students have shared in the accumulated experiences of their parents and grandparents regarding plants and pesticides. These experiences represent scientific knowledge—specifically botany and chemistry. If a teacher dismisses this knowledge as unscientific, the "student's way of making sense" is delegitimized (p. 172). The student then is cut adrift with no reference points for learning. Teachers need to value students' existing community-formed knowledge not out of some abstract principle regarding valuing diverse experiences but because of a fundamental fact of learning: "students use extant knowledge, based on culturally diverse experiences, to make sense of new experiences" (Gallard, 1993, p. 172).

The teacher can supply students with a neutral zone where they share their own constructs of the natural world with classmates and test their shared knowledge. If interaction with their peers shows students that their existing ideas do not work, they can work with other students to refine their concepts and eventually to form new ideas that reflect their experiences in class. Having supplied the student with the opportunity to identify her or his own existing knowledge and to contrast it with that of other students, teachers must offer the students activities that enable them to explore interactively and construct a new shared understanding. The teacher must structure learning activities to "facilitate science learning" for all students in the class (Tobin & Tippins, 1993, p. 5).

These activities should encourage students to use all of their senses as they build onto their pre-existing views of reality. Classroom work should offer them meaningful ways to explore new ideas with relevance to their own lives. Their learning, then, will not remain abstract but will be connected to the world as they know it. In constructivism "learning is not a process of internalizing carefully packaged knowledge but is instead a matter of reorganizing activity" (Cobb et al., 1991, p. 5). The individual student does this reorganizing in and outside the classroom.

Classroom learning, however, is not value neutral but, rather, is part of the larger culture—which the teacher usually represents. Science education will be "successful only to the extent that science can find a niche in the cognitive *and* socio-cultural milieu of students" (Cobern, 1993, p. 57). If the child's home culture does not mesh with this larger culture, the child will again compartmentalize information. The teacher may never know that school learning is contradicted in the child's home environment. The child will live in one reality at school and another at home. If the child is to integrate his or her conception of the world, parents and community must support classroom learning.

This integration will be best achieved if the teacher remains sensitive to the individuals involved. The teacher should value the fact that new ideas are being learned, not that individuals are being judged. Teachers can easily shut down the interchange between students by being too involved in the activities, by making judgmental statements, or by seeming to value one interpretation over another. In a constructivist classroom the teacher cannot accept that some students will not "get" the material. The teacher has a responsibility to present activities and learning opportunities that engage all students and enable them to form conceptions from their classroom interactions. Because classroom learning is socially constructed, all of the class will value the emerging knowledge no matter how they understand it.

In a constructivist classroom students are "ultimately responsible for judging the adequacy of their own ideas" (Thompson, 1992, p. 136). A student's ability to support her conceptions can serve as assessment of her understanding. Each student must see how his conceptions fit in with those of others in the class. From this process students build not only their own ideas about the subject, but also a shared understanding among class members. While reading and lecturing may still remain a part of instruction, other, more interactive, approaches join them in importance. Many observers believe that the valuation of individual differences in constructivist teaching makes this approach more beneficial to female, poor, and minority students (Means & Knapp, 1991).

Using constructivist methods—which emphasize hands-on-learning, concept development, collaborative learning, higher-order thinking skills used within the context of everyday experiences, and the student's construction of his or her own knowledge (Loucks-Horsley et al., 1990)—teachers can bring into the classroom a greater awareness of the relationship of the larger context to learning. When teachers encourage students to see their information holistically instead of as discrete formulas and procedures, students build more meaningful bases of mathematics and science knowledge (Mathematical Sciences Education Board, 1990; Loucks-Horsley et al., 1900; NCISE, 1989; S. Tobias, 1992).

Constructivism, however, requires a true change in many teachers' assumptions about how children learn. "If one subscribes to a constructivist view of learning, then the goal is no longer one of developing pedagogical strategies to help students receive or acquire mathematical knowledge, but rather to structure, monitor, and adjust activities for students to engage in" (Koehler & Grouws, 1992, p. 119). The teacher's role becomes pointing out conflicting solutions, facilitating small group relationships and student dialogue, guiding discussions toward fruitful contributions, rephrasing student explanations for other students, and guiding agreement on common interpretations (Koehler & Grouws, 1992). The constructivist classroom is interactional and social rather than structured and hierarchical. The teacher becomes a facilitator of learning rather than a source of knowledge. Since the teacher must value each student's interpretation of the material, students who in the past have not been engaged in mathematics and science can begin to construct their own understandings and explanations of the material. The social nature of constructivist learning often engages students who before felt isolated by the abstract nature of science and mathematics.

Cooperative Learning

Cooperative learning provides opportunities for dialogue with others, enables students to take on more complex tasks than they could working alone, and promotes higher levels of learning than other types of instruction. Research consistently finds that students of all ability levels benefit from cooperative learning.

In Japan mathematics instruction emphasizes group work and cooperative problem solving from the earliest grades (Mathematical Sciences Education Board, 1990). Many educators believe that lowering the emphasis on competition in the U. S. classroom and using the techniques of cooperative instruction could positively affect the performance and levels of engagement of all students.

In a review of the research regarding mathematics learning, Roger Johnson and David Johnson (1987) defined three types of learning situations: cooperative, competitive, and individualistic. In a **cooperative** mathematics classroom children in small heterogeneous groups are given two tasks: to learn each assigned problem and to make sure that all members of their group also learn the assignment. In a **competitive** classroom students are "given the task of solving the assigned math problems faster and more accurately than the other students in the class" (p. 69). In an **individualistic** class students are expected to solve correctly enough problems to reach "a preset criterion of excellence" (p. 69). Johnson and Johnson found that for all age levels, subject areas, and tasks, cooperative learning promoted higher achievement than did the other two types.

Cooperative learning is not small group instruction; rather it involves an opportunity to exchange in dialogue with fellow students and with the teacher (Loucks-Horsley et al., 1990) and requires a significant contribution from each group member. Slavin has identified two necessary components of small group work: group goals and individual responsibility. If small groups have no individual responsibility, the more able students will not discuss problems with others in the group, a measure of competitiveness will emerge, and the more able will do the work for the rest of the group. The group must articulate its own goals in order to make the task its own. Without both components students have no motivation to make the group work successful (Slavin, 1989a; Slavin, 1989b).

The allocation of tasks is also important to cooperative learning. The members of the group must discuss the roles needed to complete the goals of the group (Good, Mulryan, & McCaslin, 1992). Students in cooperative groups must be able to articulate what they wish to learn, how they will decide that they have reached their goal, and who will assume what roles within the group.

In a cooperative group, students learn interdependence and experience a full range of such investigative responsibilities as principal investigator, materials manager, safety officer, and recorder. Cooperative learning encourages students to take responsibility for their own learning. They can compare their own thought processes with those of their peers, tutor and encourage each other, and learn to order their thoughts. Cooperative groups can take on more complex tasks than can individual students and can be more flexible. Using such groups, however, requires an adequate amount of space, flexible seating, and additional training for teachers (Kober, 1993). Children in cooperative learning groups should come from all achievement levels: high, average, and low (Slavin, nd). Teachers should be aware, however, that "high-status" students can dominate small groups. Tasks that require different kinds of abilities for successful completion will help to ensure that genuinely cooperative work is carried out (Good, Mulryan, & McCaslin, 1992).

In 1981 Johnson and Johnson compared 122 studies of competitive and cooperative learning and their effects on achievement and performance. They found that in 65 studies cooperative learning promoted higher achievement than did competition and in 108 it promoted higher achievement than did independent work. Fewer than 10 studies found that cooperation did not promote higher achievement. These studies also indicated that medium-ability and low-ability students benefit especially from cooperative work; high-ability students may also benefit and do not suffer from cooperative learning (Johnson & Johnson, 1981).

Cooperative learning may increase the group identity of children and help them to feel a part of the school. Schools that help students to feel a part of an intimate group and that connect with students' communities and social lives produce higher achievers (Zimpher & Ashburn, 1992). At all education levels, cooperative learning may be an important part in helping students to identify with school and its work. "Working together, students soon understand that everyone knows something and nobody knows everything, and learning is speeded through shared understanding"(Steele, 1992, p. 75).

Learning Styles

Some research suggests that each person has an innate learning style born of biological and developmental influences. More controversial research holds that some learning styles are innate and connected with ethnicity. Howard Gardner's theory of multiple intelligences meshes with aspects of learning-style theory. A match between learning styles of teacher and student, some researchers say, can result in higher grades for the student. Learning style, however, is not intelligence or capacity to learn and should not become another way for stereotyping students.

Asa Hilliard defines learning style as the "consistency in the behavior of a person or a group that tends to be habitual—the manifestation of a predisposition to approach things in a characteristic way" (Hilliard, 1989, p. 67). Some research on learning styles suggests that teaching may be more efficient if it takes into account the different ways in which individuals approach learning (Dunn, Beaudry, & Klavas, 1989). While some researchers argue that poor and minority-group students tend to have learning styles that are different from those of other children, Hilliard cautions that learning styles are not innate but learned. Exposure to different environmental factors—such as teaching—can change a student's learning style. Students can also learn to use more than one style. Learning style does not of itself explain lack of academic achievement among minority students; other systemic factors are more important (Hilliard, 1989).

According to a survey of the research by Dunn, Beaudry, and Klavas (1989), each person has a preferred learning style that is the result of biological and developmental factors. Because of these differences the same teaching approach will not be effective for each student. Teachers must have available a repertoire of teaching techniques to reach the many learning styles in a typical classroom. Students, for instance, process information through different senses; some prefer auditory stimuli, others visual, kinesthetic, or tactile. Some students may use combinations of two or more senses most efficiently; for instance, a particular child may learn best by first seeing a visual presentation, such as a flip chart, and then hearing a tape. Personal factors such as motivation, persistence, need for structure, and a desire to conform may also affect learning style.

Within each learning style—visual, auditory, tactile, kinesthetic—the range of intelligences is more or less similar. The difference is not in the ability to master content but in *how* the children master content (Dunn, Beaudry, & Klavas, 1989). Most schools have evolved in ways that value a "'text-friendly' blend of linguistic and logical intelligences" (Gardner, 1991, p. 149). Students with spatial, motor, or personal interaction strengths may find school much more difficult than do those with the mixture of abilities that is more valued by schools. While linguistic and logical intelligences are important in "mastering the agenda of school," schooling that calls on all intelligences instead of only two would not only develop different types of talents but also would "make the standard curriculum accessible to a wider range of students" (Gardner, 1991, p. 81).

Students also have social preferences in learning; some learn best alone, some in small groups of peers and some in direct contact with a teacher or other adult. Students become less teacher-oriented and more peer-oriented as they enter the middle years of schooling. Small groups, thus, should become even more fruitful in junior high than they were in elementary school. By ninth grade many students begin to prefer to study and learn alone (Dunn, Beaudry, & Klavas, 1989). Gifted students may prefer to learn with other gifted students when material is difficult for them. Some studies indicate that students learn best when they are taught in several social learning styles, some of which respond to their preferences and some of which do not (Dunn, Beaudry, & Klavas, 1989).

Time-of-day preferences are part of popular lore, but several research studies have indicated that such preferences can influence learning. Studies of dropouts, underachievers, and other students considered to be at risk indicate that these students tend to be uncomfortable with morning learning. For these students, learning improved when instruction was carried on in the late morning, afternoon, or evening (Dunn, Beaudry, & Klavas, 1989). G. E. Price found that most students do not learn well in the morning. In elementary school, according to Price, only 28 percent of the students appear to be morning learners. The percentage of morning learners increases in high school, where it reaches 40 percent. At all grade levels teachers tend to be morning people who reach energy and learning lows around 1:00 p.m., just as many of their students seem to be reaching their learning peaks (cited in Dunn, Beaudry, & Klavas, 1989).

In *Varieties of Excellence: Identifying and Assessing Children's Talents*, Mindy Kornhaber and Howard Gardner (1993) call for a broader definition of intelligence that corresponds with the idea of learning styles. In previous work Gardner had identified seven types of intelligences or modes of thinking: linguistic, logical-mathematical, musical, spatial, bodily-kinesthetic, interpersonal, and intrapersonal (Gardner, 1983). Kornhaber and Gardner (1993) believe that school reform's emphasis on the learner could help students learn about their individual strengths. Realization of this possibility must overcome two American myths: that high achievement is the result of innate ability and that hard work is all that is needed to overcome obstacles. Both myths give too much emphasis to persons working alone. "In both myths, success comes from drawing upon one's own strengths, whether innate or self-forged. Thus, both help to explain some of the dearth of dedicated efforts among those who might nurture excellence in the young" (Kornhaber & Gardner, 1993, p. 9).

According to Kornhaber and Gardner, educators must recognize that excellence requires "a broad range of human competences and is realized in diverse domains" (p. 23). Working together, school, family, and community can create an environment that allows children to develop individual competencies. They recommend that teachers use cooperative learning, projects, and cognitive apprenticeships to develop different competencies. Within cooperative groups each student's abilities should be essential to group success and apprenticeships and projects should allow students to develop their own abilities at their own pace. Teachers should use experiences outside of school in designing curriculum and teaching methods, use assessment methods that are fair to those with "diverse strengths," and have students apply facts, principles, and skills to solve previously unknown problems to show that they understand a subject. Such an understanding should be taken as a marker of excellence. Furthermore "a teacher who acknowledges other intelligences as legitimate ways of knowing stands a good chance of encouraging sustained engagement among her students. Such a teacher can use a student's strengths as springboards into various areas of the curriculum" (Kornhaber & Gardner, 1993, p. 13).

Opportunity to Learn

Classroom instruction may be more important for traditionally underrepresented groups than it is for traditionally successful groups. Ascertaining what is actually taught in the classroom, then, becomes an equity issue. While opportunity to learn mathematics in Japan is apparently relatively uniform throughout the country, in the United States it varies greatly from class to class, even within the same school.

One difficulty in changing instructional practices is ascertaining what is actually being taught in the classroom. Some researchers have turned to a concept called "opportunity to learn" to develop a better idea of classroom procedures and how they relate to what students learn. The goal of researchers who have adopted an opportunity-to-learn approach is to ascertain what teachers actually present in the classroom and to compare that presentation to the "intended curriculum," or what students are expected to learn, and the "attained curriculum," that they learn. Many researchers see opportunity to learn as the most easily manipulated factor in student achievement (Porter, 1989).

The major problem in using opportunity-to-learn concepts is devising methods for ascertaining what is taught in the classroom (*Education*

Week, 28 April 1993). Generally opportunity to learn is measured by surveying classroom teachers. Teachers usually complete such surveys with information based on the specifics taught at a grade level or in a subject or course (Council of Chief State School Officers, 1993).

Floraline Stevens and John Grymes believe that opportunity to learn involves equity issues because students who have not had access—whether in their homes or in their schools—to the skills and subject matter considered average for their grade levels are at a disadvantage when taking norm-referenced tests. Low test grades are then interpreted to mean that the students did not work hard or were not capable of learning the subject matter. Frequently, however, their poor performances on standardized tests may be the result of classroom instruction. Opportunity for children to learn often hinges on the abilities of their teachers both to understand the material being presented and to make it accessible and engaging for the students. Since poor minority students may not live in environments that offer support and enrichment to supplement classroom instruction, the quality of that instruction is often more important to them than it is to students from more enriched environments (Stevens & Grymes, 1993). For female students who frequently are not taught science and mathematics concepts outside of the classroom as often as boys are, formalized instruction in these subjects may also be important.

Opportunity-to-learn factors that can contribute to classroom achievement have been identified in international studies of classroom practices. Comparative studies have identified instructional time spent on a subject as one such factor (see, for example, Sandia National Laboratories, 1993). The class time spent on mathematics instruction is much greater in Japan and Taiwan, for example, than it is in the United States (Stevens & Grymes, 1993).

The editors of *Elementary School Science for the '90s* point out that elementary students in the United States spend a little more than an hour and a half a week covering science—about the same time they spend on spelling. Elementary school teachers may avoid spending time on science because of their insecurities regarding the subject. Students from kindergarten to grade three, these authors argue, probably need to spend at least two hours a week on science and technology, and those in fourth through sixth grade should probably spend at least five hours a week. Extra time for this instruction could be found by integrating science and mathematics into other disciplines—for example history, social studies, and writing (Loucks-Horsely et al., 1990).

Most mathematics time in the elementary classroom is devoted to skill development rather than conceptual understanding and to exposing students to many topics (Porter, 1989). Kenneth Travers reports great variation in the material presented to eighth-grade mathematics classes in the United States. In some of the classes studied as part of the Second International Mathematics Study (SIMS), none of the algebra material on the international test had been presented to the students. In some of the classes all of the material had been presented. In the middle 50 percent of the classes, between 80 percent and 90 percent of the items on the arithmetic test had been taught (Travers, 1988, p. 193).

Differences in opportunity to learn in the United States are found not only between schools but also between classes within schools (Kifer, 1984). Sometimes these differences arise because of individual teachers; sometimes they are the result of deliberate decisions about which students go into which classes. Students in classes Travers identified as remedial, regular, enriched, and algebra followed "four distinct implemented curricula" (Travers, 1988, p. 195). For students who have shown themselves to be "most able" in mathematics—as measured in the arithmetic pretest—"access to algebra was independent of ethnic background." For students with "more modest ability" European-American students had much greater access to algebra classes than did students from other ethnic backgrounds (Travers, 1988, p. 195). In some schools students from poor and minority backgrounds who have shown outstanding ability may have the same access to excellent classes that European-American students of excellent ability have. Poor and minority students who have average abilities, however, will not have the same access to good teaching and classes of higher quality as do European-American students of average ability in the same school.

Other opportunity-to-learn variables that have been identified in international studies include the existence of precisely defined curricula, instructional time in the classroom as opposed to time spent giving directions, and parental beliefs in the value of effort as opposed to the value of innate ability (Stevens & Grymes, 1993). In comparative studies parent involvement in school work has emerged as an important variable. Japanese and Taiwanese parents, for example, are more likely to help their children with homework than are U. S. parents. Despite the emerging awareness that U. S. students are not competitive with their peers in other industrialized countries, "American parents, teachers, and students hold markedly lower standards for academic achievement than do their counterparts in Asia" (Stevenson, 1993, p. 63).

CHAPTER 2.7 ASSESSMENT

Assessment and Equity

Assessment could have important positive effects on equity, but as it is practiced it appears to have a negative effect. Assessment in the United States today mainly uses standardized tests to judge students, their teachers, administrators and the school districts themselves—despite the fact that standardized tests generally

encourage rote memorization and that scores on these tests have a weak relation to actual learning.

Assessment in U. S. schools reflects this society's emphasis on comparing individuals, in this case children, with other individuals. While standardized tests may not be intended for comparing one child with another, that is the common use between students and, too often, among teachers, parents, and educational institutions. For children the stakes are high. Those who score low on standardized tests are often publicly labeled as failures (Jervis, 1991, p. 4).

The stakes are also high for teachers, administrators, and school districts since assessments are used to judge them as well. Equity in mathematics and science education, it has been argued, will be achieved by greater equity in assessing not only students' progress but also teachers and programs and by using assessment tools appropriate to a reformed and revised curriculum. Alison Bernstein of the Ford Foundation has commented that "the notion that any single test can act as a gatekeeper is a notion that does not advance equity" *(Education Daily,* 15 March 1993).

Payzant and Wolf (1993) have identified two conflicting purposes of assessment in this country: "the *responsibility* to use any assessment to respond to student work and encourage growth and the *demand* that assessment provide reliable, quantifiable information about student learning" (p. 45). The first purpose, they believe, has been neglected while the second has been emphasized. Demand for accountability has resulted in an emphasis on rote memorizing for short-answer tests. Assessment could be used to encourage student understanding. Many observers assume that such assessment would more fairly represent most students' abilities.

Kenneth Dowling (1987) has pointed out that the widely used commercial tests share three characteristics. They are "designed to suit the market"; they are norm-referenced (designed to show how well a test-taker does within a group, for example, all third graders in the United States) rather than criterion-referenced (designed to show how well the test-taker does in relation to a specifically chosen standard); and they are easy to administer, score, and interpret (p. 145). National standardized tests are also "developed around a generalized model of what is being taught in grade levels or courses, usually based on popular or most-used textbooks" (p. 144). Dowling does not believe that these characteristics would be negative if the tests could go beyond recall and application, emphasize problem solving, and "measure attitudes, future science plans, values as applied to science," and other factors (p. 145).

Androula Henriques (1990), of the University of Geneva, believes that entirely new assessment tools and goals will have to be devised if equity goals are to be reached. She argues that assessments, as now constituted, are mainly tools for assuring parents that students are in the teacher's control. Testing, this researcher holds, fosters a dismal intellectual climate by creating insecurity and stress, producing bad intellectual habits, and valuing learning by rote rather than reaching understanding.

Much of the surveyed literature supports Henriques at least to a certain extent. The purported purpose of assessment is to produce information for specific uses. Teachers need to know what students know, administrators need to know what teachers have taught, school districts and citizens need to know if schools are teaching children. All of these aims are included under the label *assessment*. Assessment, however, also tells students what is valued. "What is going to be on the test" shapes what students study and the curriculum they are offered. In this function, "assessment becomes a form of communication that sends a message from the teacher or others to the student about what it is important to know" (Webb, 1992, p. 663).

Districts rely on standardized tests for monitoring and accountability. Scores are assumed to reveal valuable information about inequities between schools and can be used to rally public opinion. These tests, however, have not been particularly useful in policy making, primarily because no one has devised a way to show a relationship between improved or declining scores and expenditure of resources (NCISE, 1989, p. 26). When standardized tests are used as indicators of teaching effectiveness, teachers develop a vested interest in teaching students to memorize what will be on the tests rather than in teaching for understanding. Scores on certain national tests, the Scholastic Assessment Test (SAT, formerly the Scholastic Aptitude Test) in particular, have assumed enormous "cultural meaning" (Webb, 1992, p. 664), which has made it difficult to convince administrators, parents, and the general public that changes in testing procedures might be useful.

While the literature on assessment and alternative types of assessment is growing, little concrete research has been performed to back up ideas about what is currently wrong with assessment, the effects assessment procedures have on minority and poor children and females, and what can be done to improve matters (see Marshall & Thompson, 1994). Research investigations of individual classrooms in which alternative assessment is practiced are becoming more common, but little research has compared alternative approaches with more conventional assessments to see which works better. Studies that focus on individual classrooms have been interesting, but they have usually lacked "the critical step of describing how the new individualized assessments can be molded to work in our classrooms" (Marshall & Thompson, 1994, p. 211). While many educators appear to have reached a consensus on what is needed in assessment, evidence to back up this consensus and practical suggestions on how to use these methods in the classroom have been slow in developing.

What is Assessment?

Evolving definitions of assessment emphasize that it is a process rather than a goal or a score on a particular form.

The *Encyclopedia of Educational Evaluation* defines *assessment* as the process of gathering information needed for evaluation (Chitenden, 1991). Assessment has also been described "as providing a comprehensive account of an individual's functioning in the widest sense—drawing on a variety of evidence, qualitative as well as quantitative, and therefore going beyond the testing of cognitive skills by pencil-and-paper techniques" (Wood, 1987, p. 2). These definitions emphasize assessment as a process rather than the goal of a high score. They presume that assessment strategies and procedures will be multiple and have breadth. Within such definitions, tests—standardized and teacher generated—do not define assessment but are one component of assessment—not necessarily the most important.

Ideally, assessment should indicate that students can think about and perform required tasks and understand the material. A teacher should be able to ascertain a student's reasoning processes from the assessment, and each child should have an equal chance to display his or her abilities and achievements. When test scores are given only as a numerical score or a profile of numerical scores, a student's ability to create relationships or reason cannot be ascertained. If a teacher uses many assessment forms—qualitative methods, interviews, and observations, as well as teacher opinion—their cumulation will indicate a child's achievement level better than a single assessment can (Webb, 1992). Ideally, assessment should be a part of learning rather than a measure of one component of what a child has learned.

Changing the Testing Culture of Schools

Standardized tests have created a testing culture in the United States. If authentic assessments are to take hold in U. S. schools, the testing culture of the schools must be changed to nurture complex understanding and reflection. Everyone—students, educators, and test publishers—involved in assessment will have a part in this change.

The National Center for Fair and Open Testing estimates each child in the United States takes three standardized tests a school year (Zessoules & Gardner, 1991). Standardized tests have become such a part of U. S. schools that a "testing culture" has developed. This culture also underlies evaluation and a "standardized approach to learning" (Zessoules & Gardner, 1991, p. 48). Concern about standardized tests has led to the development of "authentic assessments," which are based on students' entire performances rather than individual tasks. Today most attempts at authentic assessment are made up of portfolios and performance-based tests that use science or mathematics centers or stations with manipulatives, measuring devices, or other instruments. At these stations students manipulate objects to explore concepts and to demonstrate their own understanding.

Authentic assessment cannot be "a matter of building fancier, better, or truer tests" (Zessoules & Gardner, 1991, p. 49). Assessment is integrally linked with instructional methods, ideas about how children learn and what constitutes ability, and conceptions of valid knowledge (Singh, 1987).

Changing assessments requires rebuilding the classroom culture. Zessoules and Gardner hold that a rebuilt culture would nurture complex understanding, develop reflective habits of mind, document the evolution of student understanding, and use assessment as "a moment of learning" (p. 51). The mechanical nature of assessment as a task that begins when learning stops would be ended by incorporating assessment into a continuum that combines assessment, teaching, and learning. When it becomes part of the daily classroom experience, assessment becomes a tool for discovering strengths rather than being a weapon for rooting out weaknesses (Zessoules & Gardner, 1991).

Changing Roles. Authentic assessment requires changes in the practices and roles of students, parents, teachers, and administrators. Students must take responsibility for their own learning and assessment. In doing this, they can use assessment as a learning tool. "It is vital that students learn to set up problem-solving strategies, decide how to organize data, identify their own mistakes, and demonstrate their own thinking as much as possible" (Stenmark, 1991, p. 14). The ability to conduct valid self-assessments is seen by many as one of the major benefits of authentic assessment practices, but, as Stenmark and other commentators acknowledge, incorporating self-assessment may be one of the most difficult parts of authentic assessment.

Teachers would no longer be the judges of students but would, through selection of materials, activities, and emphasized skills, help students achieve their self-assessments. As *Assessment Alternatives in Mathematics* puts it "the teacher is the stage manager" (1989, p. 26). This source explains, "Teachers must still help students understand what is needed, provide lessons or activities to meet their needs, identify ways for students to assess what they have done, set guidelines, and ask questions that will highlight the mathematical ideas that are important" (p. 26).

If alternative assessment is to be successful, administrators must be committed to all of these changes. They will have to give teachers the opportunity to experiment in their classrooms (Zessoules & Gardner, 1991). They will have to support teachers in developing the language needed to understand and discuss assessment in ways that make connections, share experiences, and use expertise among professionals. Most importantly, administrators will explain changes to the community and must consolidate support for new assessment forms while dealing with issues about accountability. Pressures from parents, governmental agencies and other entities may be enormous if students do not improve their test scores when authentic assessment replaces traditional forms. Parents especially may see authentic assessment as depriving their children of credentials (Singh, 1987).

Authentic assessment could radically transform our ideas of learning and evaluation, but it would be a mistake to "romanticize" the potential of authentic assessment (Zessoules & Gardner, 1991, p. 70). This process will not necessarily and automatically rise above all of the problems of standardized testing. Administrators and other "educators still need to confront issues of cultural bias, teacher fairness, validity, and reliability" (Zessoules & Gardner, 1991, p. 70).

Proprietary Problems. Publishers of standardized tests have created some of the components of the testing culture. A major problem is that the questions asked on standardized tests are proprietary secrets. In most areas of intellectual endeavor, a public and available literature reports, discusses, and debates findings (Schwartz, 1991). Standardized tests, however, are prepared and administered with no oversight from the community most affected by the results. Even if the tests contained no errors, Judah Schwartz of the Harvard Graduate School of Education believes that the costs of secrecy are still high. Since these tests control the curriculum and teaching methods of many schools, the level and tone of test questions influence students' attitudes toward a subject like mathematics or their ability to use mathematical judgment. The need for secrecy, which is often based on the economics of test preparation (questions are reused), has kept test content out of public debate. In the Netherlands, by contrast, the national mathematics tests consist of many extended problems that must be worked out in context. Tests are published after they have been used and they become part of materials available for school use (Schwartz, 1991).

Requirements of Assessment

Assessment should evaluate before, during, and after learning and should occur in context rather than as an isolated part of school. It should involve a large number of tasks rather than a single pen and paper test.

If parents and educators remember that "the purpose of assessment should be to improve learning," scoring and grading of student work will change. "Comparing students will become less important than helping students understand mathematics" (*Assessment Alternatives in Mathematics*, 1989, p. 4).

The Assessment Committee of the California Mathematics Council and the staff of EQUALS believe that assessment should focus on the individual student's ability to use mathematics and science in complex situations and in extended investigations. Assessment, they add, should be based on the ability of a student to form and refine hypotheses, to collect and organize information, to explain concepts orally or in writing, and to work with poorly defined problems or with those that have more than one answer—problems, in other words, that more closely resemble real situations.

Mathematical processes should be observed in context rather than in isolation. Assessment should gauge the extent of a student's understanding or misunderstanding of mathematical concepts and the student's ability to define and state problems. Change over time should also be observed (*Assessment Alternatives in Mathematics*, 1989). Many observers believe that individualized assessment will especially benefit female students and those from minority groups or low socio-economic backgrounds, but this belief has not been rigorously tested.

Many educators also believe that assessment would be made more equitable if it were conducted during learning activities rather than after instruction has been completed. (See, for example, Loucks-Horsley et al., 1990; NCISE, 1989.) The use of authentic experiences and tasks, observations, open-ended questions, structured interviews, written problem-solving assignments, computer-assisted assessment systems, portfolios, and student reports and self-inventories can all open up the assessment process. Flexibility, awareness of cultural diversity, and an emphasis on conceptual and contextual thinking would seem to be more available with authentic assessments than with traditional forms (NCTM, 1991). Teachers should develop multiple assessment methods, formats, and modalities that result in several measurements for forming a representation of a student's performance (California Department of Education, 1992).

In fact, unless alternative assessments include a large number of tasks, they may be poor indicators of student achievement. In deciding what a student knows or can do, "determining a student's abilities in a variety of situations is more important than obtaining a single score on a highly reliable test" (Webb, 1992, p. 668). A study by the Center for Research in Evaluation, Standards, and Student Testing at University of California, Los Angeles (CRESST, 1993) found that measurement error in performance assessments largely resulted from variability in task sampling. Student performance varied greatly between sampled tasks within subject areas or domains. Nancy C. Jordan and her colleagues found that low-income kindergarten children performed addition and subtraction calculations better on nonverbal formats than they did on any of three verbal formats (Jordan, Huttenlocher & Levine, 1992).

Student test performance will be affected if teachers adopt constructivist or other alternative teaching strategies. If such changes are made, a gap may form between instruction and the test content if traditional tests are retained (Chitenden, 1991). Unfortunately, teachers may find new assessment techniques labor-intensive. Alternative assessment also demands that teachers function as "clinicians with deep understandings of cognitive mappings in various content areas" (Marshall & Thompson, 1994, p. 215). Most teachers may lack skills required by this function.

Concern about accountability will also affect changes in assessment. Classroom data will have to be organized in ways that make sense to students, teachers, parents, administrators, and community leaders. The major goals in redesigning assessments seem to be taking advantage of and reflecting **actual classroom work,** enhancing **teacher and student involvement** in evaluation, and meeting **accountability** concerns (Chitenden, 1991).

New assessment procedures differ from the conventional in many ways: They are **cumulative** and **open-ended**, use a **variety of settings**, are **theory referenced** rather than norm referenced, and are **teacher mediated** rather than teacher proof (Chitenden, 1991).

Different Assessments for Different Students

> **Gifted and special education students, speakers of languages other than English, those who use nonstandard English, and other categories of students may need special assessments. Alternative assessments may fail minority and other underrepresented groups unless schools ensure that teaching methods are congruent with the new assessment forms.**

Different students require different assessment procedures. For example, gifted children who are not from the suburban white middle class may be less verbal and more passive in class than other gifted children. Assessments to identify children who are gifted in science and mathematics may miss these children unless the different expressions of their abilities are taken into account (*Education Daily*, 13 May 1993).

Traditional assessments administered to groups of children are unlikely to identify gifted children who are poor readers or underachievers or students whose first language is not English. The ideal in such situations is individual tests administered by people with experience with learning disabilities, bilingual children, underachievement, or reading problems. No single assessment is adequate for identifying "the multifaceted nature of giftedness" (Hooker, 1993, p. 54).

In 1990 Mary Frasier devised the Frasier Talent Assessment Profile (F-TAP) to identify gifted children by using many different types of data from different sources. "Identifying gifted kids who are minorities isn't simply an issue of finding a better test," Frasier holds, but rather of using information from educators and parents regarding how they identify gifted children. She has identified rich vocabulary, ability to comprehend abstract ideas, knowledge about a variety of things, higher-level thinking skills, rapid learning, unusual learning abilities, and retention of knowledge as some of the characteristics of gifted children. Minority children who display these characteristics, however, often do not do well on standardized tests (cited in Alexander-Kasparik, 1992). Teachers will have to change the ways in which they notice the traits of gifted children when they are expressed in different ways—ways that are congruent with different backgrounds and cultures. Staff development, on-site coaching, and other forms of support will foster such changes in teachers.

Changes to include more alternative assessments will particularly benefit students whose facility in English is limited or nonexistent, those who speak or write nonstandard English, and special education students. If necessary, students who do not speak English or whose English is not standard should be provided with translators (*Assessment Alternatives in Mathematics*, 1989). Special education students should be given the opportunity to display previously undetected gifts through portfolios, performance tasks, and other active assessments. The move away from normed tests as the sole measure of eligibility and advancement in Chapter 1 programs will require other assessment methods, particularly to show advanced skills (*Assessment Alternatives in Mathematics*, 1989).

When test questions and assessment tasks are presented only in written English, poor readers and children whose first language is not English will not be able to show their true levels of mathematical or scientific understanding. In addition to presenting tests in children's native language, other alternative questioning and assessing practices could include manipulatives, videotaping, computer-based presentations, and "teacher-taught introduction" (Mathematical Sciences Education Board, 1993, p. 10). The student can present her or his response by constructing objects, creating patterns on computer screens, or explaining solutions to the teacher orally. Children who are inexperienced in writing often have an easier time explaining their reasoning orally. Even children with experience in writing answers may often deepen and sharpen their responses with both written and spoken explanations.

Translation of test questions is a task that requires delicacy in language use. When questions and other assessment procedures are translated into Spanish, for example, question designers must be aware of the differences in the varieties of Spanish within the United States. The authors of *Measuring Up* (Mathematical Sciences Education Board, 1993) translated some of their prototypes but noted that they had used the informal form in their translations. Students from Costa Rica, for example, would not be accustomed to this form in such situations.

Members of the community and other sources outside of the school may be good sources of information for individual teachers and the school district when multilingual tests are being devised.

In March 1993 a coalition of the Educational Testing Service, the College Board, and leading education researchers outlined some principles for education reformers that they believe will result in curricula and assessments that are fair to students of all backgrounds (*Education Daily*, 15 March 1993):

- Assessments should be **tested** in the field with **diverse populations.**
- **Minorities** must be **included** in the development of standards and assessments to evaluate progress.
- **Standards** must be **public** and must make clear the skills and knowledge children will need when they leave school.
- Assessment **options** should be offered when progress is evaluated.
- **Guidelines** should be set to indicate how schools will use standards.
- Tests should be **published** after their use.
- Reformers must be sure that schools will have the **resources** to support standards and other new methods for improving learning.
- Everyone involved must understand which methods and tests new versions will **replace,** and the schools' role in **implementing the new instruments** must be clarified.
- **Teachers** must be **included** in developing standards and assessment.

Coalition members add that reformers must make it clear that money spent on reforms may limit the amount of money available for other areas of school work. They also stress that schools should not use tests or other assessment procedures merely to indicate their success in educating children. This practice is "a way of doing something about education without doing something about investing in education," as Linda Darling-Hammond, dean of Teachers College, Columbia University, said (*Education Daily*, 15 March 1993).

Unless these alternative methods are used wisely, they can widen the gaps between white and minority students and between well-off and poor schools. On the 1992 mathematics assessment used by the National Assessment of Educational Progress (NAEP), the difference between European-American and African-American students was substantially larger on open-ended questions than it was on standard multiple choice and short answer questions (*Education Week*, 23 June 1993).

The NAEP data show that on average 20 percent of European-American fourth graders gave answers that were satisfactory or better on open-ended questions, but only 5 percent of African-American fourth graders did. The numbers do not improve as the students move through the grades: In eighth grade 10 percent of European Americans and 2 percent of African Americans produced satisfactory or better responses, and in twelfth grade 10 percent of European Americans and 4 percent of African Americans produced such responses to open-ended questions.

On standard multiple choice questions for the twelfth grade 59 percent of European Americans and 46 percent of African Americans answered correctly.

Several possible explanations exist for these differences in performance on open-ended questions. black students, for example, may be less likely than white students to receive the kind of instruction that allows them to work out their own answers (*Education Week*, 23 June 1993). Whatever the explanation, these results indicate that alternative assessments in themselves cannot be treated as answers to equity problems. Without integration with the rest of schooling, alternative assessment may be detrimental to equity concerns.

Assessing Programs

If programs are to be accurately assessed, students, teachers, administrators, and parents must all forsake tests that make everyone "look good" for authentic assessments that accurately identify whether or not good instruction is taking place.

Continuous assessment of programs is needed as mathematics and science education changes. Educators need to know whether programs are meeting their goals, how resources are being distributed, and what the emerging strengths and weaknesses of programs are. Such assessment is easier if general guidelines are used to assess the program. The NSTA plan for self-assessment, for example, offers many useful self-assessment tools, including checklists regarding program characteristics to be used by principals (Loucks-Horsely et al., 1990).

Teachers, administrators, and parents will have to turn away from measuring that makes students and teachers "look good" and try instead to determine whether a school is providing conditions that allow for good instruction. These conditions will include "time and the opportunity to learn, facilities, materials, staff preparation, and expectations" (NCISE, 1989, p. 34). Assessment of programs must also deal with factors that contribute to teacher satisfaction: salaries, class size and pupil load, clerical support, teacher voice in decisions, principal support for professional development, and "time for school-based, collegial goal setting, program planning, curriculum development, and staff development" (p. 36). While having these conditions and factors present will not ensure that good instruction will take place, without them teachers cannot be effective. "Collecting and displaying information about these enabling conditions may be, in the short run, the best way to counterbalance the negative effects of limited outcome measures" (p. 34).

CHAPTER 2.8 Culture Inside and Out of School

Schools, students and their families, teachers, and administrators all exist within specific cultures and subcultures. Students and teachers bring into the classroom cultural attitudes and expectations that influence their behaviors and attitudes. The expectations of cultural minorities may support or conflict with the expectations of the official culture that is most apparent in the classroom.

Attitudes toward science and mathematics are also learned from the culture at large. Among the general cultural ideas that reduce interest for many students is the belief that success in science and mathematics requires innate ability rather than individual effort. Female and minority students are particularly vulnerable to this idea. Given the predominate cultural stereotypes, individual female and minority students or their parents or teachers may begin to believe that they do not have the "mathematical mind" or the "scientific mind" to achieve success in those fields. Another negative cultural factor is the belief that scientists and mathematicians are eccentrics with little interest in people or normal relationships. Maintaining status with peers is a powerful influence in keeping many students away from serious study of any subjects, and especially of science and mathematics (Kober, n.d.a; Kober, n.d.b).

African-American Cultures

> **The congruence or incongruence between the cultures of most black young people and that of "mainstream culture" has been investigated by many researchers. Schooling has traditionally been considered a vital part of African-American cultures. If schooling could be "re-energized," education might regain its central position.**

Many observers claim that a specific cultural attitude affects some black young people's ability to succeed in school. One of the more controversial writers in this area is Signithia Fordham, an assistant professor of anthropology at Rutgers University, who has focused on the causes of underachievement among black youth. Fordham, who grew up during the years of the civil rights movement, says she was supported in academic achievement by her parents and the African-American community (*Education Week*, 9 June 1993). While she says she felt some peer pressure to avoid success, the prevailing pressure on her and her generation of upwardly mobile young African Americans was "to get good grades and be good citizens" (quoted in Schmidt, 1993, p. 13).

Fictive kinship. Fordham believes she has found a very different culture among some high school-age African Americans today. In 1982 she began field work observing and interviewing youths in an unidentified high school that she called Capital High School, located in a section of Washington, D.C. that is predominately African American. Capital High is not a low-income, low-status school. The school's advanced placement program attracts students with a broad spectrum of interests and abilities and racial and socio-economic backgrounds from the District of Columbia area (Fordham, 1993).

She found that many of the students she observed had parents like hers who pushed them to succeed academically. A countervailing force came from what Fordham calls "fictive kinship," which she says symbolizes peoplehood in opposition to the prevailing white society. "I never believed it would be so pervasive and so pronounced, and so academically stifling," Fordham says of these pressures (quoted by Schmidt, 1993, p. 14). Fictive kinship, she holds, tends to lead young people to see their own chances of success as linked with the chances of their peers and their community. Group loyalty assumes an even stronger emphasis in situations that involve conflict or competition. Often that group loyalty rejects excelling in schoolwork as "acting white." Seeking to reaffirm their group membership, students may sabotage academic success when schools and teachers view group behaviors negatively (Fordham, 1991; Fordham, 1993).

According to Fordham, academically oriented African Americans are often caught in a bind. They may try to distance themselves from fictive kinship and to develop what she calls "racelessness." This quality, however, can result in rejection by peers, loss of self-confidence, and loss of a feeling of belonging (*Education Week*, 9 June 1993).

Critics of Fordham's research point out that all students in U. S. culture today feel peer pressure to avoid academic success. They add that many other factors—societal, economic, and individual—affect the academic success of African Americans.

Caste stratification and cultural inversion. Fordham's work is an elaboration of John Ogbu's cultural ecology theory. Writing in the late 1970s, Ogbu held that poor school performance of African Americans was the result of the U. S. caste or racial stratification system. Ogbu (1978) defines a group as a *caste* if it is seen as "inherently inferior" by the majority and is stigmatized and excluded. Training and ability have no bearing on the roles society assigns to members of a caste.

According to this premise, African-American children have failed to succeed in school because they could see historically that effort expended in schoolwork had not benefited African Americans. Equality of educational opportunity is meaningless unless it includes "equality of access to postschool rewards of formal education" (Ogbu, 1978, p. 5). African Americans know that having a degree may not be as important in later life as race. In the early 1980s high school dropouts from wealthy white New York neighborhoods were more likely to be employed than were high school graduates from poor black neighborhoods (Tobier, 1984). Schools must begin to realize that African Americans connect the work of education with the roles of the adult world. "So long as caste remains the principle of social organization no efforts to use the schools to equalize the social and occupational status of different minority and majority castes can succeed" (Ogbu, 1978, p. 359).

In a 1990 update of his views Ogbu added that involuntary minorities (those groups, such as African Americans, Native Americans, and Hispanics of the Southwest, whose ancestors did not consciously and voluntarily migrate to what is now the United States but who were either already here or were brought here against their wills) often practice "cultural inversion." In this process members of the minority cultures reject as inappropriate events, symbols, and behaviors that are characteristic of the dominant culture. Such survival techniques, developed over long periods, may be difficult for these minority groups to change, even when and if members of the majority culture change their behaviors. Cultural inversion strategies may continue in the minority cultures because they have been useful for so long (Ogbu, 1990).

Congruent structures. When teachers use language and participation structures that are "congruent" with those of the students' homes, African Americans participate to a greater extent in classroom exchanges (Mehan, 1992). Most of the original research in this area was concerned with community college students, but some of it focused on the Westside Prep School of Chicago, where Marva Collins has had well-publicized success with her alternative teaching strategies. Collins attributes her success to a curriculum that emphasizes phonics for young children, but the research "gave more credit to the congruence between Collins' interactional style and the children's cultural experience. Familiar language and participation structures, including rhythmic language, call and response, repetition, and deliberate body motions, constituted the interactional pattern" (Mehan, 1992, p. 6).

The triple quandary. While most studies of the academic achievement of African Americans have focused on school failure, Theresa Perry (1993) believes that a more interesting question is how African Americans have nurtured and socialized children for more than 200 years. Perry believes that discussions of school achievement need to focus on the "extra-cognitive, social, and emotional competencies" African Americans need for school success. African Americans must meet conflicting demands in order to become socialized as competent adults. African Americans must negotiate a "triple quandary," according to Perry, as simultaneous members of three groups: mainstream society, the black community defined as a racial minority by the dominant culture, and the black culture "in opposition to which whiteness has been constructed as a social category" (p. 2).

Perry points out that historically African-American culture has always valued schooling and has seen the school as more than a site of instruction and preparation for the job market. The African-American school was also the site of citizenship, leadership, and racial uplift.

African-American schools were places where children were highly valued for themselves and where adults expressed that valuation in their words and actions.

In her study of the Caswell County (N.C.) Training School, Emilie V. Siddle Walker (1993) emphasizes the central place of the school in African-American communities before integration. Contemporary school reformers can learn much, she believes, from the successes of such schools in the past. Parents and adult members of the black community who had no children felt an investment in the school. Despite difficult work schedules and transportation problems, parents attended Parent Teachers Association meetings in large numbers and supported the school financially and morally. In contrast with the relationships in many modern urban schools, teachers and parents in Caswell County offered each other support and respect.

The adult roles were different from those common today. Parents, for example, did not help their children with homework and teacher-parent conferences were not scheduled. Instead, the functions of educators and parents were clearly separated and interactions between the two tended to be informal. Given these differences, Walker "wonders... if African-American parents and White teachers and school leaders are operating out of different frameworks for parental involvement. Perhaps schools apply dominant cultural definitions of good parental involvement...,while African-American parents lean towards more traditional perceptions and modes of interaction" (p. 177–178). Walker describes a school and community that were closely linked and depended on each other. In contrast, as Michelle Fine has pointed out, schools in urban communities today offer themselves as "the only way out of Harlem" (Fine, 1989, p. 154), rather than as part of the community.

Perry suggests that the historical link between schooling and uplift should be "re-energized" in today's society so that education regains its central place in African-American culture. To accomplish this aim, she suggests, schools, families, and other institutions can begin to structure experiences so that biculturality is emphasized. The culture of the school can help students negotiate their multiple memberships so they succeed in school rather than reject the school as a cultural opposite. Schools should not make cultural codes oppositional but rather should emphasize the goal of fluency in many different cultures. Emilie Walker would add that schools and their teachers and principals should "become advocates for, rather than adversaries in, their students' communities" (p. 179). Schools should stop asking how they can get black parents involved in the education process and begin asking "Why did they stop supporting schools and what can be done to eliminate the barriers so they will come back?" (p. 180).

Other Cultural Factors

Cultural respect in the classroom is not a matter of heroes and ethnic holidays but respect and an openness on the part of the school to a wide range of acceptable meanings. While teachers and schools must be sensitive to the cultural backgrounds of their students, culture cannot be used as a justification for giving certain groups of children nonchallenging work.

Students' competing worlds. While mainstream education is teacher-centered and emphasizes evaluation of right and wrong answers from the student, socialization in most Native-American and Hispanic cultures emphasizes cooperation and peer relationships. Native-American children often will not answer a question until all other children in the class are ready to answer, are uncomfortable in situations that require them to interact with adults rather than other children, and may "have great difficulty with direct questioning techniques employed in most school situations" (Charbonneau & John-Steiner, 1988, p. 92). These cultural preferences may carry over into other situations, such as teacher-parent conferences in which direct questions will not reveal parents' actual thinking.

The peer expectations of Hispanic students can interfere with individual academic goals. Patricia Phelan, Ann Locke Davidson, and Hanh Thanh Cao (1991), all of Stanford University, give the example of a young woman they call Donna, who would often neglect her own schoolwork in order to help other students complete theirs. Donna, in an attitude the authors present as typical of an Hispanic world view, does well in classes "where she perceives the teacher as caring and where the norms and behaviors that characterize her family and peer worlds—group over self, listening and emphasizing with others, and mediation skills— are required" (p. 240). When Donna sees a teacher as distant or cold and the classroom does not use the cultural skills she values, Donna does poorly and her "attention shifts to peer-group concerns" (p. 240). In an analysis of research studies of noncontent factors related to assessment, Hembree (1987) also found that test takers "of low socio-economic status" improved their scores when the test was administered by someone with a warm and enthusiastic personal style.

The Multiple Worlds Model. Phelan, Davidson, and Hanh have devised the Multiple Worlds Model, which they believe will help educators focus on what most affects student learning. During a two-year study of 54 students selected to reflect the diversity of four California high schools, the researchers noted that these students used a variety of strategies to negotiate the boundaries between their family, school, and peer worlds and that these strategies varied within ethnic groups. They believe teachers should arrange classroom interactions to facilitate students' attempts to cross the boundaries that separate the classroom from family and peer groups without requiring that students "give up or hide important features of their lives" (p. 246).

Many students from minority groups successfully negotiate the difficulties of dealing with mainstream European-American male-centered schooling. Teachers who "are aware of their students' precarious academic status and incorporate various pedagogical methods to ensure student involvement" are most successful with those who have difficulties negotiating the boundaries between school, home, and peer (p. 245). Students usually could be classified into one of three categories regarding their ability to negotiate different worlds.

The worlds are congruent for some students; in these situations all transitions between worlds will be smooth. For others these worlds are not congruent. Some students with incongruent worlds can manage crossing boundaries between them, but others find the crossings hazardous. For the third group of students the worlds are totally impenetrable and no crossings can be made (Phelan, Davidson, & Hanh, 1991). Teachers need to try to ascertain the students' cultural congruences and to obtain help when students cannot maintain interrelationships.

Teaching styles. Cultural differences also affect teacher styles. Inuit teachers observed by Alice Eriks-Brophy were more indirect in their work with kindergarten and first-grade children than were European-American teachers. Teachers who were Native Americans avoided singling out individuals for praise or blame, encouraged peer models by guiding students to listen to each other, allowed overlapping talk, were willing to wait for long periods for responses, and laughed with delight often (*Education Daily*, 16 April 1993). In a second study different researchers had more difficulty sorting out cultural behaviors, but they did find that teachers who were Native Americans emphasized a cultural bond with their students, valued preservice and professional development training very little, and ignored their teachers' guides and other classroom conventions. The researchers in this study felt that these experiences were common to all good teachers of whatever ethnic or cultural groups, but others believe that a "cultural renaissance" of Native-American values is occurring in education (*Education Daily*, 16 April 1993). Jerry Lipka (1991) reports that the research continues to indicate that teachers are more successful in teaching children with whom they share the same ethnic origins, even when the teachers are not as well educated as other teachers might be. Lipka believes that the sense of kinship created in the classroom generates "civility" and "cooperation" in place of conflict and resistance (p. 204).

Some researchers attribute poor performances by Native Americans to a clash between the "structures of participation" demanded in the typical classroom and those to which the children are accustomed in their homes (Mehan, 1992). Schools that emphasize competition and individual performance do not foster achievement among Native Americans as well as schools that "minimized the obligation of individual students to perform in public contexts" (Mehan, 1992, p. 6). Many Native-American students function best in classrooms that emphasize cooperation over competition and sociality over individuality.

Leap (1988), however, has found that poor mathematics performance among northern Utes is associated with many factors, including student commitment to traditional Ute ideals of self-reliance and independence, which make it difficult for students to look to others for help. Traditional Ute counting and grouping methods also often conflict with the school's principles for the same procedures.

The U. S. Department of Education (1991), in its report *Indian Nations at Risk*, has found that "schools that adjust their curriculum to accommodate the variety of cultures served are more successful than schools that do not" (p. 16). This generalization undoubtedly applies to more schools and cultures than the Native American. The success of these schools involves respecting and supporting the student's language and culture in the school. Respect does not merely involve incorporating famous names and ethnic holidays into the classroom, but a match between the meanings, processes, and behaviors encouraged by schools and those valued within the student's culture. "A widening of the range of acceptable meanings is a signal by the school that it accepts cultural diversity as a real, normal, and permanent feature of society" (González, 1993, p. 259). Josué M. González believes that such changes cannot be made through materials or the adoption of new district policies, but only through classroom activity. "The change that is needed is chiefly in the professional behavior of school personnel" (p. 260). If schools are to reflect the cultural communities in which they exist, each school will have to "create its own plan for democratizing the meanings and values that it conveys to children" (p. 268).

Competing languages. Language may be another key, for "the language providing the greatest potential for intellectual development is the language reinforced in both the school and the home" (U.S. Department of Education, 1991, p. 16). Much research indicates that performance in mathematics improves when students are instructed in their first language. When Spanish was used as the language of mathematical instruction for Hispanics who were Spanish dominant, their performance equaled that of non-Hispanics. Student errors increased when the language of performance and the dominant language were not the same (Cocking & Chipman, 1988, p. 35).

The New Standards Project, a consortium of 17 states and several school districts to develop performance standards, assessments, and professional development, has a specific advisory group to advise on designing and administering "tasks that will enable students who are learning English to display their competence in English and their native language" (Simmons & Resnick, 1993, p. 15). The reform group has also made efforts to include scholars and others with knowledge regarding language, gender, and cultural issues on all of its advisory groups.

Nonremedial culture-based teaching. *Indian Nations at Risk* also found that students' understanding of their own culture and of its and their own role in the larger society is directly related to their ability to function in that larger society: "When students' relationships with the larger society are strained, their chances for academic success appear to diminish" (p. 22). The findings of this report would appear to be relevant to other cultural and ethnic minorities in addition to Native Americans.

T. L. McCarthy and coworkers have warned that research into the differences among ethnic learning styles should not be used to justify "remedial, nonacademic and nonchallenging curricula" for students from minority groups (McCarthy et al., 1991, p. 43). Kathryn Au has pointed out that Native-American children are not nonverbal or linguistically handicapped but that "there are settings in which they may appear so" (Au, 1979, p. 92). Teachers who have been trained to expect that certain types of children will be passive or will not ask questions may never give those children an opportunity to engage in "active, open-ended discussion" (McCarthy et al., 1991, p. 54). If teachers have only a shallow understanding of their students' cultures and then use that understanding to form simplified and conventional "representations" of learning styles, the simplifications will result in a stultifying pedagogy that debilitates children (McCarthy et al., 1991, p. 54).

Female students and cultural expectations. The expectations of the larger culture continue to affect the way females view mathematics and science, although some ethnic groups do not appear to share in the general idea that women should avoid these subjects. MacCorquodale (1988) studied Mexican-American parents in Arizona who tended to stress the importance of education for all their children but were more likely to discourage girls from pursuing nontraditional careers than were the non-Hispanic white parents in the study. Campbell and Connolly indicated that European-American parents support girls in their decision to avoid mathematics and science. Asian-American parents, however, did not practice this "over-protective" behavior. Bernice Sandler has found that, in the general U.S. culture, scientific or mathematical success by men is attributed to talent and women's success is attributed to luck or hard work (both studies cited in *Dwight D. Eisenhower Mathematics and Science Education Newsletter,* 1993).

Many young women who are interested in mathematics or science in grade school never develop those interests, in part because of social pressures but also because of problems within the disciplines themselves. More than young men, young women often perceive science and mathematics courses as dull and lifeless and the people who choose careers in these areas as having no room in their lives for anything other than their work.

Magnet programs in science and mathematics tend to be "structured to mirror a boy's emotional development" (Finkel, 1993, p. 35). At Montgomery Blair High School in suburban Maryland many young women dropped out of the science and mathematics magnet program to return to their home schools. The program's early emphasis on physics and computers was not interesting to these students, even though many had been identified as talented in mathematics and science. A teacher asked one female student why she did not like the emphasis on computers and pointed out "some boys in the computer lab who were busy typing away. 'They like it,' he said. 'They'll sit there all day.' 'Yeah,' the girl said, 'but look at the social skills of those boys'"(Finkel, 1993, p. 35).

Even young women who are acknowledged by teachers, parents, peers, and the wider educational community as having special gifts in science and mathematics must deal on a daily basis with emotional and social situations that seem to escape the understanding of male students and teachers. A *Washington Post* reporter, David Finkel (1993), describes the attempts to enter a class discussion made by Elizabeth, identified by her teacher as "the best" or at least "number two" in his class on quantum physics, considered the most difficult class offered in this magnet school (p. 33):

> Steve talks. Josh interrupts. Steve mumbles. Josh interrupts that. Steve grabs a marker, goes to the board, and tries to work something out. Josh goes to the board, too, using one hand to draw and the other to hold a cheese sandwich, which he has been wolfing down.
>
> And through it all, Elizabeth sits, listening.
>
> She tries to say, "Wait" and falls silent.
>
> She tries again. "Soooo," she manages to get out.
>
> She tries a third time, this time snapping her fingers and lightly slapping the table, and finally, after that has failed, she gets up, draws something on the board, and explains in her always polite way, a way that often turns a statement into a question, that maybe this is the way to look at what they've been talking about?

If a young woman who scored 1570 (out of 1600) on the SAT and made perfect 800 scores on her achievement tests in both mathematics and science can experience this much difficulty in entering a discussion, imagine how less gifted young women must feel in similar situations.

Social conditioning and stereotypes about both science and women help keep young women out of science. Women do appear to be more interested in disciplines that involve social values. As some have pointed out, when science and engineering are presented as fields that help people or the environment women express more interest in them (Alper, 1993).

Religion and the scientific culture. A particular problem of cultural sensitivity in the teaching of science involves religion. Phelan, Davidson, and Hanh (1991) point out that for many students the "family world may be dominated by an all-encompassing religious doctrine in which values and beliefs are often contrary to those found in school and peer worlds" (p. 232). In the United States official conflict between students' religious worlds and school worlds often focuses on the teaching of evolution in the public schools. This contentious issue has recently captured headlines in several parts of the country.

In California the state has recognized evolution as a unifying theme for the science curriculum. At the same time several groups across the country have mounted a strong challenge to the sole teaching of evolution in science classrooms and have demanded that various anti-evolution theories—and especially what is called scientific creationism—be offered equal time in the science classroom. Opponents of scientific creationism maintain that it is religion masquerading as science and creationists counter with the same charges against evolutionary theory. Creationists charge that those who oppose them are restricting the "right of teachers to teach a variety of scientific theories" (*Education Week*, 8 September 1993) and describe themselves as a persecuted minority (Nelkin, 1982). Scientists respond with the view that "concepts of pluralism, of equity, of 'fairness,' of wide-open participatory democracy as practiced in a political context are irrelevant to the context of science" where "decisions are based on the existence of an organized body of knowledge" (Nelkin, 1982, p. 186). Those who favor teaching creationism in the science classroom can be portrayed as arguing for more diverse teaching and those who favor evolution as the framework for teaching biology can be presented as trying to limit the area of discussion (Garcia, 1991, p. 23).

Students who hold other religious views also may have difficulties in the science classroom. Native Americans often see the use of science to obtain control of the physical environment as threatening to traditional beliefs (Caduto & Bruchac, 1989). Wilifred Denetclaw, Jr., a Navajo and a zoologist, experienced this threat as a student at Fort Lewis College when he had to dissect a cat to pass vertebrate anatomy. From childhood Navajos are taught not to touch or even refer to the dead. Denetclaw went on with the dissection and explained that he had to decide that "the Great Spirit would know why I'm doing it, and it would be okay" (Levy, 1992, p. 1231). Among Native Americans who have totem animals, their connection to the totem indicates their closeness to the natural world and may preclude other approaches to that animal—such as dissection (Caduto & Bruchac, 1988).

In the classroom science teachers must deal with the different philosophies regarding the natural world of various religious groups. Is it the science teacher's job to see that ideas about nature are treated equally? Or is it the science teacher's job to see that the body of knowledge defined by the mainstream of the scientific enterprise as *science* is made available to students? Should students who object to evolution be allowed to leave the classroom when it is discussed, much as Jehovah's Witnesses have the option to leave during the Pledge of Allegiance? If allowances are made for those who object to evolution, what arrangements should be made for students who have ethical objections to dissection or for children from Christian Science homes who object to the germ theory (Edwords, 1983, p. 313)? If teachers "teach the truth of their disciplines," can they also "respect the beliefs and values of students and their parents" (Garcia, 1991, p. 57)?

CHAPTER 2.9 The Creation of At-Risk Students

The Definition of At Risk

The phrase at risk is borrowed from epidemiology. Its use in education is often inexact and controversial.

The structure of the school, the attitudes of teachers and students, cultural values, and administrative practices all interact in complex ways to give rise to the concept of the at-risk student. This description is applied to a student who is "at risk" of not doing well in school because of various social, economic, and psychological factors. Equity must consider this concept since many students who do not do well in school and who come from poor or ethnic minority backgrounds end up with this label.

The idea that students are at risk for doing poorly in school because of social, economic, or other factors is fairly new. As of 1989 the term *at risk* did not have its own listing in ERIC. A search for this term would have referred the reader to the phrase *high risk students*, which has been in use since 1980. Related terms under this listing, however, included *low achievement*, *underachievement*, and *disadvantaged*, all terms that have been in use since the 1960s. While the term itself is relatively new, it includes older concepts (Richardson et al., 1989).

The concept *at risk* comes from epidemiology, the study of patterns of disease distribution and the factors that affect those patterns. For example, men who are overweight and smoke are more at risk for heart disease than the general population, although all people have the possibility of suffering from this condition. The job of the epidemiologist is to identify those in the greatest risk category. Even in epidemiology the concept is not considered exact; two limitations must be observed in using the term in medicine: When a population is so labeled the condition for which they are at risk must be identified. Second, being at risk is relative since everyone may be at risk for a condition, such as heart disease, to greater or lesser degree (Richardson et al., 1989, p. 4). When the concept is used in education these limitations are often not observed.

Even within medicine the identification of risk based on social characteristics is considered inexact. When the model is moved into education to identify students at risk of failure or dropping out, identification based on social characteristics becomes not only inexact but also controversial. The epidemiological model is now dominant in education; this use of a medical label not only gives a scientific air to an inexact process but also hides and limits the ways educators think about the problems involved (Richardson et al., 1989).

Social Constructivist Model of Being At Risk

The constructivist model of at-risk factors emphasizes the interaction of social, personal, economic, political, and educational forces in creating a child who faces the possibility of academic failure. Being labeled at risk may be more detrimental to a child than the features the label is meant to describe.

Richardson and her colleagues have devised a model of at-risk factors based on social constructivist thought rather than medicine. In this interactive model the student who is at risk, the reasons for this labeling, and the responses of school personnel are all seen as constructed within the classroom. The student brings personal and background factors to the classroom where she or he will interact with other students, teachers, and materials. These classroom factors will affect the outside factors. In addition, the classroom is affected by the larger school and even by the district. In this model the focus is not on the child alone but on interaction within a series of contexts (Richardson et al., 1989).

From the beginning of their study, Richardson and her colleagues assumed that the at-risk concept involved interaction between the school's social and academic setting and the student's own background factors, such as ethnicity and socio-economic factors. The student's at-risk label, they assumed, was affected by the organization of the school and the classroom, the teachers' norms and expectations, and the tasks students were expected to perform. Their final assumption was that labeling can damage a student more than the characteristics the label is meant to identify.

This social constructivist model suggests that interactions between the teacher's expectations and the student's nature and classroom actions are integral to the construction of at-risk status. Social, political, and economic constraints also make the model operate in similar ways in different classrooms. The school context shapes the way teachers perceive student behavior. Teachers see certain competencies as necessary within the school context, but these competencies are not always necessary in other environments, say, at home. The expectations of the school or the district may also affect the teacher's willingness to label a child at risk. Some districts or schools, for example, may show more concern for a child's social or emotional development, while others may focus only on perceived academic problems when considering whether or not the student is at risk of academic failure (Richardson et al., 1989).

An example of this process at work is found in *Lives on the Boundary* (1990). As a teacher, Mike Rose began to work with Harold, a fifth grader with a series of twitches, tics, and grimaces. When he had entered the school in first grade, Harold had scored high average in reading readiness, but one teacher report after the other showed increasing frustration with the child's unpredictable behavior and distraction. By second grade he was labeled below average. In Harold's file, Rose "saw how his teachers had increasingly misread his tics and twitches and detachment as signs of organic damage, how they had gradually despaired of helping him, how he was progressively defined by the school as the outsider....The folder displayed the sad and elaborate chronicle of what happens to a child who is too distressed to fit neatly into our classrooms" (p. 120).

Harold's file revealed his teachers' tendency to reduce his complex behavior to a medical model that ignored the child's real needs. "His past was being replaced by a sterile chronicle of assessments that couldn't get to the living center of his problem: his lost father, the mother receding slowly into a dim parlor, the growing weight of the assumption of his feeblemindedness. Harold was made stupid by his longing, and the folder full of tests could never reveal that" (p. 127). Tests and the remedial procedures that followed them had harmed Harold by officially defining him as marginal and strange. Despite initial signs of ability, Harold had been defined at a young age by judgments about his abilities. These judgments had followed him through school and shaped his teachers' responses to him and his responses to them. The poorer children are and the less power and knowledge of the school system their parents have, the more likely it is that their lives will be categorized by such an accumulation of assessments (Rose, 1990).

Teachers' lack of understanding about the way their own perceptions and behaviors shape the identification process can lead them to assign all causes of at-risk behavior to a student's home life and family members. In making this assignment of cause teachers work from their own ideas of what a "good" family is—an idea that has much in common with their construction of the ideal student. Working with this ideal, teachers can usually find something wrong with the home life of any student who is perceived as behaving inappropriately in the classroom. In this way the teacher can refrain both from blaming the behavior on the child and from having to make changes in the classroom or in his or her methods of interacting with children (Richardson et al., 1989).

While such approaches may result in inaccurate labeling of children as at risk or of homes as deleterious to children's learning abilities, they may also deprive other students of needed attention. Children whose behaviors fit within the teacher's expectations may not be recognized as being at risk and may never receive help that they need. A 1986 dissertation by C. N. Goldenberg (cited in Richardson et al., 1989) found that Hispanic girls are generally not diagnosed as having learning problems because they are skilled at covering up such problems.

Instructional Strategies for At-Risk Students

Interventions for at-risk students should accelerate instruction not slow it down. Pull-out programs may not be beneficial for at-risk students. Systemic changes will be of the greatest use to students in this category.

Accelerated remediation. Some approaches that teachers use with students they have identified as at risk may be more useful than others. Richardson and her colleagues found that remediation that accelerates the pace of instruction is more successful with students who fall behind in their studies than instruction that is slowed down. Although this idea appears to be counterintuitive, slowing down breaks up instruction into pieces that are so small they become "meaningless and boring." As instruction is slowed down the gap between the student and the rest of the class becomes wider, expectations are reduced even further, and mechanics are emphasized over substance. These factors combine to keep the student from ever catching up with the rest of the class. Merely accelerating the traditional curriculum is not the solution, however. Presenting material in new and challenging contexts may especially benefit such students (Richardson et al., 1989).

Pull-out programs. Richardson and her colleagues believe that pull-out programs create more problems than they solve. The diagnostic procedures used to determine whether or not a child is at risk and should be using a pull-out program are often based on unreliable self-fulfilling tests. In a pull-out program specialists may teach students needed skills in ways that cannot be transferred to the classroom. The sporadic nature of pull-out programs also fragments instruction for children who already may have difficulty in integrating learning.

The most insidious problem of pullout programs, however, is that they relieve the classroom teacher, the school, and the district from making systemic and other changes that may be beneficial for all students. Providing "stable and coherent social-educational" programs and reorganizing schools so they can respond rapidly to problems of individual students may be more important than offering pull-out programs (Richardson et al., 1989).

PART 3:

Strategies for Achieving Equity

What is to be done then? In schools, university research projects, and public arenas across the country various strategies have been tried in an attempt to answer this question. Some strategies have been tested in rigorous scientific settings; others have been recounted in more impressionistic reports of what some educators perceive to be working in the classroom. Strategies targeted to specific populations and those aimed at improving instruction for all students have been tried, but how is success at achieving equity measured?

How will policy makers and the public know when equity has been achieved at the personal, school, state, regional, or national level? Should success be gauged by a general increase in the scientific and mathematical understanding of all the population or by the numbers of previously underrepresented people going into science and mathematics-connected professions? Will reform in mathematics and science education have achieved equity when more of the traditionally underrepresented groups sign up for high school science and mathematics courses, complete such courses with high grades, or enter colleges intending to major in fields within these disciplines? Walter E. Massey (1992) has also asked how one is to measure "success in science." Is equity in these fields measured by an increase in minorities and women who become "star scientists" who open new areas of innovation and thought, or by an increase in those who become everyday scientists working on less glamorous tasks?

A definitive answer to these questions is hard to come by. Programs and approaches described in this section do not adhere to one strategy and do not present a specific answer to any of these questions. Rather approaches designed to achieve a general mathematical and scientific literacy and programs aimed at specific populations and groups have been included.

CHAPTER 3.1 Approaches Targeted to Specific Populations

Many programs targeted to specific populations have been aimed at female students and at students from minority groups. Fewer seem to have been constructed specifically to provide services for rural students or students with disabilities.

Strategies and Programs Specifically Aimed at Female Students

Female students may learn science and mathematics best in an all-female environment that emphasizes hands-on

and cooperative learning. Several successful programs for young women also emphasize mentoring.

Data and experience indicate that females may learn science and mathematics-related subjects best in an all-female environment (Alper, 1993). Women's colleges have a higher retention rate for female scientists than do coed colleges and universities. Emphasis on hands-on work and cooperative learning also seems to attract more women to science.

Hands-on classroom work. Bridget Dalton, a Harvard lecturer on education and project director of the Education Development Center, and her colleagues focused on fourth-grade Boston girls in eight classrooms with 171 students. The researchers concluded that both boys and girls appear to benefit from hands-on methods of science instruction and that girls perform as well as boys when classroom instruction emphasizes such learning (Dalton et al., 1993).

Teachers from the eight classes received a day of training, two after-school coaching sessions, and subsequent technical assistance. The students were then given a six-week unit covering electrical circuits, a topic Dalton chose because she believed it is generally considered a more "masculine" area of science than, say, animal observation. Students were divided into same-gender pairs to conduct experiments. After the unit was completed virtually no gender difference was evident in the students' achievement (Dalton et al., 1993).

Before the instruction began, boys and girls had indicated "comparable levels of electricity knowledge" in their responses to a questionnaire (Dalton et al., 1993, p. 4). During the hands-on instruction the girls' level of understanding and grasp of applications remained the same as the boys'. The girls "performed comparably to the boys on even the most difficult concepts, such as parallel circuits" (p. 5). Boys and girls showed a range of mastery; students from both sexes were distributed naturally into low-achieving, average, and high-achieving groups.

Dalton and her coworkers believe that their results show that "challenging hands-on science" (p. 5) can result in girls being as successful at learning and conducting science as boys. The hands-on science benefited the learning of a broad range of students, including those with and without learning disabilities, low- and high-achieving students, and urban and suburban students.

Using same-sex pairs may also have improved performance. Girls who worked in same-sex pairs were more active in class discussion than they had been previously. Dalton and her colleagues believe that pairing may be more beneficial than working in the typical lab group of four or five. More research must be completed, however, before the effects of same-sex work and working in pairs are differentiated. Dalton's study is part of a larger study funded by the Office of Special Education Programs in the U. S. Education Department.

Young women from the fourth grade through the tenth grade are targeted by a program developed by the Lawrence Hall of Science at the University of California, Berkeley. Through the EQUALS Teacher Education Program, staff have designed activities to stimulate young women's interest in scientific careers, develop their problem-solving and visualization skills, and encourage positive attitudes toward mathematics and science. Female students are introduced to the language and tools of science, mathematics, and technology. An assumption of the program is that young women are less likely than young men ever to have handled tools or to have been introduced to the ordinary concepts and terminology of using such equipment as hammers and saws (Lawrence Hall of Science, 1982).

The program uses activities involving a range of mathematical topics. Students are given an opportunity to learn about the requirements and descriptions of jobs that use mathematical knowledge and to use common tools. After becoming familiar with the tools, the students design several construction projects. They also design workspaces for a veterinarian and in the process learn about engineering, architecture, drafting and other occupations. Where the EQUALS program has been in effect for two or more years, the interest of young women in advanced mathematics classes has increased slowly but steadily.

Extracurricular activities. Many programs aimed at young women use extracurricular activities to supplement traditional classroom instruction in science and mathematics. These extracurricular activities tend to emphasize learning in a same-sex environment. Several of these programs are targeted at the junior high years, since many observers believe that this period is when young women begin to feel pressure to hide their intelligence and allow boys to better them in the classroom (Travis, 1993). No formal research on extracurricular activities appears to exist and the information is anecdotal.

The question of whether boys must be excluded from the learning environment if girls are to succeed in science was raised by the experiences of an all-girl science club in Boston. The club, made up of fourth-grade girls from a small suburban school, had been organized by the mother of one of the girls who was concerned that her daughter might lose her interest in science and mathematics as she grew older. Designed to emphasize hands-on work during camping trips, visits to planetariums and museums, and other experiences, the club was invited to compete in the seventh annual battle of LEGO robots, sponsored by the Massachusetts Institute of Technology. The girls placed well in a field that included college undergraduates and graduate students and teams from high-technology firms in the area. Under the tutelage of one girl's father, a computer scientist, the girls' club designed a robot that was to move as many foam rubber blocks as possible to a designated spot. The father who advised the girls believes that the dynamics of the group would have been changed if boys had been included. The girls, he thinks, would have been less willing to take risks and make mistakes in the presence of boys (Travis, 1993).

Traditional extracurricular organizations for young women have begun to experiment in offering girls more science-based activities. Both Girls Incorporated (formerly Girls Clubs of America) and Girl Scouts have begun programs that encourage science activities among their members.

Girls Incorporated offers Operation SMART (Science, Math, and Relevant Technology) for elementary and junior high school girls. About 250,000 girls in 240 clubs participate in the project. The Ford Foundation evaluated the project and found that, although attendance is not compulsory, a majority of the participants attended the science night regularly. A survey of the girls in one urban club found that their occupational goals had changed from secretary, nurse, and teacher to scientist and engineer after participating in the program (Travis, 1993).

The object of Operation SMART is to give girls an attitude of scientific inquiry that will encourage them to question, observe, take things apart, make mistakes, and take risks. The clubs emphasize projects like building cameras, investigating the interior of a copier, dissecting bird nests, and disassembling machines. In addition to the emphasis on hands-on activities, the club sponsors trips to workplaces and contacts with role models and mentors. Operation SMART hopes to encourage interest in science and mathematics that will carry the girls through their junior high years.

Hands-on experience and mentoring are also part of the program sponsored by the Girl Scouts. The American Association for the Advancement of Science (AAAS) developed a program called Girls and Science, which was then tested by Girl Scout troops in Minnesota and North and South Dakota. In these troops the number of science-related merit badges the girls earned increased by 57 percent after the program came into use. A grant from Abbott Laboratories has made it possible for AAAS to train scout leaders in Wisconsin and Illinois.

Teachers, scout leaders, and other interested adults learn active educational techniques in workshops led by AAAS staff. Training is conducted at 25 sites and ultimately reaches more than 100,000 girls. The concentration is on using common household items in hands-on science and mathematics activities so that the experiments seem both familiar and practical. In addition to involving girls in science and mathematics, the program aims to overcome the lack of scientific and mathematical interest and preparation of most elementary school teachers and others who have regular contacts with young women. The program has changed the attitudes of the parents of the young women who participate. Seeing their daughters enjoy science projects in their troop meetings has challenged adult stereotypes regarding women and science (Travis, 1993).

The University of Michigan has sponsored two summer programs to interest precollege girls in science. Both programs emphasize hands-on experiences. In Summerscience for Girls, eighth graders from around the state come to the campus for two weeks, attend seminars, and participate in projects in engineering, natural resources, chemistry, physics, and space science.

Science for Life, a second University of Michigan program, places older high school women in the laboratories of women scientists for six weeks during the summer. Half work in laboratories at the University of Michigan Medical School and half work in research laboratories at Werner-Lambert Pharmaceutical Co. The students work on their own research projects and participate in a symposium at the end of the program. A major goal of the program is to show high school women that research has a social aspect and is not necessarily solitary (Travis, 1993). No follow-up data on these programs are available.

A similar program is Careers in Engineering for Women, held on the campus of The University of Texas at Austin each summer. Sponsored by the State Engineering and Science Recruitment Fund of the Texas Education Agency, the program brings 100 seventh and eighth graders to the campus for two one-week sessions in which they engage in hands-on laboratory sessions designed to develop mathematics, science, observation, problem-solving, and critical thinking skills. Practicing female engineers act as mentors to the students, who also interact with engineering professors from the university faculty (TEA, 1993).

Strategies and Programs Specifically Aimed at Students from Minority Groups

Cooperative learning in small study groups, emphasis on taking challenging courses and developing good study habits, culturally relevant materials, peer support groups, mentoring and involvement with the student's family and community are features of several programs aimed at students from minority groups.

Most of the programs targeted at minority groups that were identified through this review emphasize building **support** for students with academic interests through peer group or adult mentor support. They use study groups, clubs, and other peer-age groups to foster interest in science and mathematics. Several do not emphasize innovative teaching methods, such as hands-on instruction, as much as they emphasize preparing students to **cope with existing structures**, such as the SAT, that might filter them out from a college education. Information on results in the classroom is sketchy and generally involves students' scores on standardized tests.

Group studying. California-based Mathematics, Engineering Science Achievement (MESA) focuses on ensuring that African Americans, Hispanics, and Native Americans attend college and at least consider mathematical and scientific careers. MESA also has programs in other states, including New Mexico. MESA began in the late 1960s when Wilbur Somerton, head of the petroleum engineering group at the University of California, Berkeley, began to work intensively with 25 Oakland students of average abilities. Most of these original 25 eventually graduated from four-year colleges. In California, more than 70 percent of the MESA students enroll in four-year colleges, although statewide only 13 percent of minorities enter college (Gibbons, 1992b).

At all educational levels MESA emphasizes study groups and academic advising. It offers enrichment programs, career counseling, scholarships, and family involvement programs for secondary school children and workshops, orientation, summer jobs and other aids for college-level students. MESA's program for Native Americans, Success through Collaboration, offers a culturally relevant curriculum. A three-day summer conference demonstrates mathematics and science teaching activities for secondary-school teachers. Private industries affiliated with the program sponsor field trips, offer materials and personnel to supplement school budgets, and contribute to the budget. The major emphasis of the program remains developing peer and support groups that can encourage a student's desire to excel academically.

Somerton says that the secret to MESA's achievement is requiring that students take demanding courses and backing them up with any needed help. MESA requires students to attend study groups that provide them with good study habits and, more importantly, a peer group that supports and approves of academic achievement (Gibbons, 1992b). Somerton emphasizes that MESA's success is achieved with average students, not the academic cream of the crop.

Academic enrichment. The Texas Prefreshman Engineering Program (TexPREP), in contrast, concentrates on high achievers rather than on average students. TexPREP identifies high-achieving middle and high school students from sixth through eleventh grade. These students attend eight-week mathematics-based academic enrichment programs. The summer programs are usually held on college campuses and are staffed by college faculty, undergraduate science and mathematics majors, and high school teachers. Students may participate in the summer program for three years. The emphasis is on logic, algebraic structures, problem solving, and probability and statistics. Field trips, guest lecturers, and involvement with local scientists and engineers are part of the program. TexPREP is open to any high-achieving student but female students and students from minority groups are targeted. Of former participants responding to a 1992 survey, 74 percent of the science and engineering majors were from minority groups (TexPREP, 1993; Berriozabal, 1992).

Test preparation. Several programs try to ensure that average students from minority groups stay in school, take more science and mathematics classes, and attend some form of postsecondary education. Venture in Education (VIE), sponsored by the Macy Foundation, began with students from high schools in Brooklyn, Harlem, and rural Alabama and now includes 39 schools across the country. Open to any student who wants to sign up, VIE requires four years of English, mathematics, science, and social studies; two years of foreign language; advanced placement classes in biology, calculus, English, or social studies in addition to the regular requirements; and attendance at specially designed summer academic programs and SAT preparation classes (Gibbons, 1992b).

About half of the VIE graduates responded to a 1992 questionnaire. Of this group, 90 percent of the minority students were attending college. Minority VIE graduates tend to enroll and major in science disciplines more than the general population of minority students. Almost 15 percent of the African Americans from the program were majoring in the biological sciences, compared to 0.2 percent for African Americans in college across the nation (Gibbons, 1992b).

Another program that emphasizes sending minority group students to college, Partnership to Improve Minority Education (PRIME) was organized in 1988 by the College Board, the Educational Testing Service, and the Hispanic Higher Education Coalition (Sherman, 1992). Administered by Arizona State University, the program has developed school improvement strategies that reached 22 high schools and 60 elementary and junior high schools in 1992. While PRIME mostly affects rural schools, the program focuses on children from minority groups. The PRIME's goal is to double the number of minority students continuing postsecondary education and triple those majoring in science, engineering, or mathematics.

Algebridge, a PRIME program, is designed to help junior high students move into algebra. PRIME emphasizes teaching students to achieve well on traditional assessments, such as standardized college entrance tests, rather than introducing innovative instructional methods. Staff members train teachers and administrators in PRIME's methods before a school year begins and offer follow-up assistance. In Clifton, Arizona, eighth graders moved average mathematics scores on the Iowa Test of Basic Skills from the 29th percentile to the 48th after a year of Algebridge. PRIME also offers a 25-hour course in test-taking skills to familiarize students with college-entrance examinations and test-taking strategies, trains teachers in teaching advanced placement courses, and offers enriched science and mathematics activities to schools. Those who devised the program consider involvement of the students' families to be crucial to the program's success. PRIME helps families find scholarships and other financial aid and helps parents become involved as advocates for their children.

PRIME's emphasis on involving the family and the entire community in education is important to the program, as is its attempt to make sure its approach fits in well with the ethnic lives of the students. PRIME staff is ethnically diverse—three African Americans, three Hispanics, two Native Americans, and two whites. Parent meetings can be held in Spanish or many Native-American languages. The staff tries to hold parent meetings in churches, community centers, or homes, rather than schools. Many families, they believe, associate schools with authority and negative experiences. Staff members think that sensitivity to the feelings of previously neglected populations is as important as the academics of their program (Sherman, 1992).

PRIME prepares minority students to cope with the gatekeeper aspects of standardized tests. Other programs are trying to change the ways in which tests are formulated. Some programs are geared to younger children and do not emphasize the need to pass standardized tests and go on to college as much as they emphasize the learning of basic skills.

Teacher development. Another approach to improving classroom performance and achievement for children from minority groups is to focus on teacher training. This approach appears to be especially useful for elementary schools. The Minority Mathematics and Science Education Cooperative (MMSEC) is open to Texas elementary schools in which a majority of the students participate in reduced and free lunch programs and come from minority groups and disadvantaged families.

A collaboration of public elementary schools, universities and colleges, and the Texas Higher Education Coordinating Board (THECB), MMSEC offers elementary school teachers training to increase their conceptual knowledge of mathematics, earth or life science, and physical science; their teaching skills and practices; and their knowledge of their students' cultures. MMSEC uses an annual institute, with nine-month sessions based in the individual schools, and annual summer courses to bring this information to the teachers (THECB, n.d.).

Each summer, site teams—made up of higher education teachers, district curriculum supervisors, principals and key teachers from each participating school—attend a week-long training of trainers, to be trained in the particular affective and cognitive strands offered that year. While each school may chose the strand it wishes to follow in a given year, the cognitive and affective strands follow an exact order. In the first year the strand labeled Gender/Ethnic Expectations and Student Achievement attempts to make teachers aware of how their expectations affect their interactions with students. In the second year the Cultural and Contextual Learning strand shows teachers how to use cultural and contextual resources to improve mathematics and science teaching. In the next year, the Parental Involvement strand helps teachers and principals learn how to involve parents in their children's education. The last year is devoted to reinforcing the previous years' learning.

At monthly workshops in their schools teachers and principals continue to work with higher education trainers. Principals and key teachers pass this learning on to other teachers in faculty meetings and through peer coaching. MMSEC also offers intensive college-level summer courses in science and mathematics for 35 teachers from each site. Team-building and leadership training are also part of the program (THECB, n.d.)

Mentoring. Mentoring can be very important to students of color at all stages of education. Students who stay in a science or mathematics career track often credit their perseverance to a role model or mentor who insisted that they do their best work. Role model and mentor influence can counteract the low expectations that other authority figures often have for minority students.

A nationally recognized program, the Incubator Scientist Program (ISP) identifies promising young people from minority groups in the St. Louis schools. ISP exposes these students to scientific research and pairs them with an African-American adult in the science and technical industries of the area. Run by former chemistry teacher Edward Haynie, the program involves junior and senior year high school students in the formulation and research of a scientific problem under the long-term guidance of an adult mentor.

With funds from the National Science Foundation and administrative support from the University of Missouri, St. Louis, the program relies on teacher recommendations to choose students. The program is highly individualized and so the number of students who can participate must be limited. During the summer before their junior year the incubator scientists attend a five-week summer academy that immerses them in mathematics, science, and English. Each student then chooses a research topic and is assigned an adult mentor. In the second program year students attend another workshop, continue to work on their projects, and become student mentors to the new crop of ISP students. ISP students, thus, have both an adult mentor in the scientific community and a peer mentor. Out of the program's first group of 11 students, 10 attended college (Allen, 1993).

Since 1976 the Texas Alliance for Minorities in Engineering (TAME) has joined industry, educators, government, and parents to inform and motivate students about science and engineering. In addition to offering summer enrichment programs and tutoring programs, TAME assigns mentors from industry to work with each student. The mentors tutor students, advise them about career choices, and help them find summer employment in science and engineering areas. TAME originated when Dallas industry notified higher education institutions in the area that they were having trouble recruiting members of minority groups into engineering positions. Between 1976 and 1991, minority enrollment in engineering programs in the state increased by 55 percent (Texas Alliance for Minorities in Engineering, n.d.).

Strategies and Programs Aimed at Specific Language Groups

Students with limited English proficiency appear to benefit from programs that use collaborative learning and hands-on activities. Improvement in science and mathematics learning can have positive effects on other domains also.

Finding Out/Descubrimiento. The Program for Complex Instruction at Stanford University focuses on school difficulties faced by students whose first language is not English. About 15 years ago the program developed science activities for a San Jose, California, elementary school. Concentrating on younger children, primarily from low-income, Spanish-speaking families, the program worked on basic skills and learning by doing. In small groups, children performed science tasks related to everyday life. The program cost was small since most materials are readily available.

While the goal of this program was to improve science abilities and understanding, the researchers found that the students improved not only in their scientific and mathematical abilities but also in their ability to read and speak English. Student interaction in small groups and the need to read task cards (which use cartoons with captions in both Spanish and English) affected language abilities (Gibbons, 1992a).

The Program for Complex Education has now published its multiple-abilities curriculum under the name *Finding Out/Descubrimiento* (*FO/D*). The published material now includes activities for middle school as well as elementary school students. Available in English, Spanish, and pictographs, the materials deal with developing higher-level thinking skills in heterogeneous classrooms (Larson, 1993/1994). *FO/D* emphasizes cooperative learning and is meant to be "an alternative to teacher-dominated direct instruction" (Secada, 1992, p. 652). Activities apply mathematics and science to real-life situations. Materials include instructions, worksheets, activity cards, and manipulative materials. *FO/D* has been extensively tested and validated and is funded by the National Science Foundation and the Walter S. Johnson Foundation (Larson, 1993–1994).

Kids Investigating and Discovering Science. Language is also an important part of the approach to science and mathematics education in KIDS (Kids Investigating and Discovering Science), based in Irvine, California. The teachers in this program speak to their students in any appropriate language—Spanish or Japanese or English. Aimed at kindergarten through eighth grade, KIDS is based on the idea that all children can learn about science whether or not they know English (Gibbons, 1992a).

Hawthorne School strategies. Eleanor Wilson Orr (1989) and her colleagues at the Hawthorne School have devised several strategies for "breaking the habits of depending on patterns" that speakers of Black

English Vernacular may fall into. In one method they help students realize what they are actually doing when they use algorithms by working with nonstandard irregular number systems in which place values are changed, can be more than ten times the value of the position to the right, or can fulfill many other variable changes. Students can invent their own place values. In a second method students are freed from "dependence on numerical patterns" by visualizing symbols through drawing diagrams and symbols that depict the relations of numbers and of fractions to whole numbers. In such exercises students can see "why the *number* of pieces (the numerator) in the product has to be the product of the numerators in the multiplier and multiplicand" (Orr, 1989, p. 208). Such lessons force students to push the limits of their language and then to use new language tools to open new areas of thought. Students have to abandon old language-based memorization tools they have used to fake their way through classes. The Hawthorne teachers have found that Euclidean geometry is the best material "in providing students the opportunity to experience language as a tool with which to think" (Orr, 1989, p. 211).

Gifted language-minority children. June Maker and her colleagues are trying to increase identification of gifted children among language minority students. They have developed a series of problem-solving tasks to identify students who have a potential for academic success otherwise hidden by their limited English abilities. Children are asked to build objects, tell stories, solve geometric puzzles, use pieces of cardboard to build shapes, and solve other problems presented to them. Maker believes that the biases and limited views of intelligence found in most IQ tests make it impossible to use them to identify giftedness among students who are limited in their English proficiency. She has devised a test based on the ideas of Howard Gardner, who believes that giftedness can be expressed in many domains, including spatial, musical, and kinesthetic.

Others besides Maker are working on identifying gifted students with limited English abilities. A widely used nonverbal intelligence test is Raven's Progressive Matrices, which calls on children to solve problems using abstract figures and designs. This test, however, does not measure all forms of intelligence and must be used with other tests. A test developed by Edward A. DeAvila uses cartoon-like illustrations and is primarily employed as a preliminary screening device for young children (*Education Week*, 26 May 1993).

Strategies and Programs Specifically Aimed at Rural Students

Little research has been carried out on improving science and mathematics education in rural areas. Access to natural settings and familiar experiences are assumed to be potential benefits for hands-on training in rural schools.

Overcoming isolation and gaining access to new instructional technologies remain problems.

While many of the programs discussed so far affect female and minority children in rural, urban, and suburban schools, few programs are particularly aimed at all children in rural schools. While some rural schools can be among the most neglected and poor schools in the country, some are quite wealthy. Most observers believe that smaller and more isolated rural schools would especially benefit from cooperative learning and multigrade classrooms, site-based decision making, distance learning technologies, and integration of curriculum and service. While technological and structural changes would probably benefit rural schools, many seem to be unable to adopt these changes at least in part because of political considerations: Rural schools often cannot qualify for grant money to adopt expensive technological improvements. Additionally, local sentiment in many rural areas opposes consolidation or similar restructuring plans that might be financially and academically beneficial. Little research, however, has been conducted to test success in science and mathematics classrooms in rural schools.

Teacher-training programs. In Texas the Rural Elementary Science Improvement Project is part of the Texas Alliance for Science, Technology and Mathematics Education (TASTME). This program emphasizes workshops for rural teachers and offers a combination of weekend hands-on science and mathematics workshops offered during the school year and intensive two-week summer programs. Since the program's inception, more than 900 elementary teachers have taken part in the one-day workshops and 200 teachers from every level have participated in the longer programs. All training focuses on helping teachers develop curricula that incorporate applications from everyday life and teach problem-solving skills (Texas Governor's Office, 1991; TASTME, 1992).

In Oklahoma a program jointly funded by the University of Tulsa, the National Science Foundation, and cooperating school districts sponsors workshops to strengthen rural teachers' understanding of basic physics and chemistry. The summer workshop has sponsored 25 teachers each year since 1988. These teachers are not necessarily trained in science, but the program introduces them to hands-on methods to increase their scientific confidence and enjoyment (SCIMAST, 1993).

To meet some of the needs of rural education in its region the Northwest Regional Educational Laboratory (NWREL) has also focused on training teachers in new teaching techniques. Since the summer of 1990 NWREL has administered Science and Mathematics Academy for Rural Teachers (SMART). The academy brings teachers from rural schools with the smallest enrollments in the region to a two-week academy during which they meet teacher education coordinators from five participating universities and persons from two public science centers and a national energy laboratory. In state-level planning sessions, teaching leadership strategies are also disseminated. Teachers from each state have met each year since 1990 to plan for state academies. Those who have participated in the program report that they have formed alliances with other rural teachers and educators, have developed a greater sense of themselves as innovators, have introduced new methods into the classroom, and have developed ways to use local and community resources in a better way. No information on classroom results appears to be available (*Dwight D. Eisenhower Mathematics and Science Education Newsletter*, 1993).

Gifted rural children. Indiana-based Project SPRING (Special Populations Resource Information Network for the Gifted) looks for giftedness among rural Appalachian children in the southern part of the state. Students are chosen from recommendations sent in by teachers and parents. Those in the program are asked to complete projects, such as designing a dwelling for the night, that tap different kinds of intelligences and use rural knowledge. Program designers believe that these tasks will more accurately measure the abilities of rural students than can standardized tests, which, they hold, are biased toward urban criteria of knowledge (*Education Daily*, 13 May 1993).

Learning technology. Remote learning technologies offer rural schools access to a more challenging curriculum, but rural schools should not expect these technologies to take the place of personal contact with a teacher. Their apparent cost-effectiveness is built on passing costs to other groups since outside funding from state or federal sources is often required to obtain these systems (Sherman, 1992).

Since 1987, Oklahoma State University, with some funding from the National Science Foundation, has brought advanced placement chemistry classes to small rural schools. Live instruction by satellite is made available to schools that offer the first year of chemistry but have no facilities or manpower for subsequent years. Students can question the video instructor and can respond to the instructor's questions. Using computers, students compare data from experiments conducted in their school laboratory with data from other schools. The school's chemistry teacher supervises the class and interacts with university researchers running the project (SCIMAST, 1993).

In rural schools the fundamental problem may still be access to computers, not their cost-effectiveness or their inappropriate use. Each year a quarter million computers are placed in U.S. schools, but rural schools often find that they are trapped in a limbo between state and federal responsibility when they apply for money to purchase equipment. These schools are also more likely to be preyed upon by sellers trying to get rid of hardware and software that will soon become obsolete (Alexander-Kasparik, 1993).

Project development and research reporting remain incomplete in the study of improving the rural instruction. Outcome data in this area are limited or nonexistent. Rigorous comparisons between projects have not been made. Rural education appears to be neglected not only by policymakers but also by educational researchers.

CHAPTER 3.2 Reaching All Children with Reform in Science and Mathematics Education

Many organizations and projects are based on the idea that changing the science and mathematics education of all children will strongly benefit previously underrepresented student populations.

Children come to school with an informal home-based understanding of the natural world and numbers. In 1981 Ginsburg and Russell pointed out that all children enter school with backgrounds that enable them to cope with these systems; it is school that changes this disposition. Once in school students must connect their informal learning with the formal contexts of the classroom, a task that often proves impossible.

Schools, then, must foster students' early predisposition and help students explore and test their own understandings as a precursor to developing new knowledge. Many observers believe that this fostering will best be carried out through programs that affect all children and go beyond textbooks to emphasize experiential, hands-on learning that draws from the communities in which children live (Charbonneau & John-Steiner, 1988).

Developers of several widely publicized programs believe that raising the quality of science and mathematics teaching for all students is the best way to improve the academic performances of traditionally underrepresented groups. The drive to establish standards in various disciplines, as well as national initiatives like Project 2061, Scope, Sequence and Coordination, and Equity 2000, has been aimed at entire district, school, or classroom populations rather than at specific groups. All are new and have little to report on effects on student achievements.

The Standards Movement

Standards that establish a core of knowledge that each student can build on to improve his or her understanding are assumed to benefit all students. Mathematics standards have already been formulated and science standards are being prepared. A consensus on the role standards should play in U. S. education has not been reached.

In 1989 the NCTM released *Curriculum and Evaluation Standards for School Mathematics*, the first major document in the recent movement for "standards" in education. The NCTM *Standards* explicitly recommended that tracking into the two sequences of college preparatory and general mathematics be abandoned in favor of three years of mathematics involving a core of common topics for every student (NCTM, 1992a). "The promise of the Standards...is that all students, including underrepresented minorities, will have the opportunity to learn more, and somewhat different, mathematics" (Johnson, 1990).

The teaching of mathematics advocated by the NCTM *Standards* differs from traditionally taught mathematics in that it involves active learning on the part of the student and collaborative work among students in the classroom. In addition, it emphasizes broad topics within the field: mathematics as problem solving, as communication, as reasoning, and as connection. These four broad standards "frame a curriculum that ensures the development of broad mathematical power in addition to technical competence" (NCTM, 1992, p. vi). Working from within these broad areas, teachers should form material at a depth and breadth of presentation appropriate to each student's level of competence. No student should have his or her needs unfilled if the core programs are sufficiently differentiated. "Our expectation is that all students must have an opportunity to encounter typical problem situations related to important mathematical topics. However, their experiences may differ in the vocabulary or notations used [and] the complexity of the arguments" (NCTM, 1989, p. 9).

Although science standards are not yet available, the National Research Council has formed the National Committee on Science Education Standards and Assessment (NCSESA). The NCSESA intends to produce an integrated work of curriculum, teaching, and assessment standards that will reinforce each other (NCSESA, 1993a). The committee has issued several drafts for critique by teachers and others. The goal is to have a finished version by the end of 1994. NCSESA has tried to "enlarge the mainstream of...science" by involving such groups as the Association for Women in Science, the American Indian Science and Engineering Society, and the Foundation for Science and the Handicapped in the development and review of the standards (Hoffman & Stage, 1993, p. 31). Parents, business people, policymakers, and the wider education world have also been included in the process.

The framers of the science standards assume, as did those who wrote the mathematics *Standards*, that enunciating a set of standards will help to assure a level of understanding for all students (NCSESA, 1993a). The standards are intended to meet the needs of each student from kindergarten to grade 12 "regardless of background, circumstance, primary language, or ambition" (NCSESA, 1994). A guiding NCSESA principle is that the standards "should be limited to the fundamental understandings and should offer selection criteria that states, localities, teachers, and students can use to determine additional subject matter to be studied" (Hoffman & Stage, 1993, p. 31). The criteria will include material that is connected to experience, is developmentally appropriate, is worth the effort teachers and students must expend to reach understanding, and contributes to the students' investigative and decision-making abilities (Hoffman & Stage, 1993).

Not all observers agree on the power of the standards. Catherine A. Brown and Hilda Borko, for example, point out that the NCTM documents "provide the direction, but not the mechanism for reform in school mathematics" (Brown & Borko, 1992, p. 235). They add that, while the NCTM *Standards* are accepted within the mathematical education community as guidelines to the "best thinking," little systematic research has guided the construction of the standards.

Michael Apple, while generally supportive of the NCTM *Standards*, believes that a danger exists that they will be read "in a social and economic vacuum" (Apple, 1992, p. 417). Where will schools find the funds to create the rich classroom environments that the NCTM describes? Apple also points out that the *Standards* do not address the deeper questions of the uses of knowledge. "Mathematical and scientific knowledge is not just any knowledge. It performs specific functions currently—functions that are tied to the kind of economy that we have" (Apple, 1992, p. 421). Whose definition of important mathematics is used in the *Standards*? What real-world problems do the *Standards* identify as worth pursuing? Apple sees the *Standards* as lacking "a far more detailed understanding of the complex and contradictory roles that mathematical knowledge may play in an unequal society" (p. 425).

Nationally Recognized Programs

Some programs aim at curriculum reform and some at a more comprehensive restructuring of education for all children. Changing the attitudes of teachers and counselors regarding the abilities of their students is a part of some projects. While some projects are concerned with basic classroom procedures and actions, others take a more abstract and general approach to changing entire subjects.

Some programs for reforming science and mathematics education for all students are national in scope. Project 2061, sponsored by the American Association for the Advancement of Science, and Scope, Sequence and Coordination (SS&C), sponsored by the National Science Teachers Association, are two of these and are often seen as similar projects. Both educational reform efforts are designed to improve science education for all students; both emphasize that more students than only the intellectually superior can learn about and enjoy science and mathematics (AAAS, 1993). While opposing the teaching of isolated science facts, both have proposed alternatives to the traditional structure and content of science courses. Both believe that depth of understanding is preferable to memorization of facts and formulas and that technology should be a component of science education. Each program has sites throughout the country and tries to involve all components of the community—teachers, administrators, parents, and others. Each is funded by the National Science Foundation and emphasizes life-long learning.

Despite these similarities the two programs do have different emphases. Project 2061 is a systemic reform effort aimed at all aspects of scientific literacy in grades K through 12, while SS&C addresses curriculum reform in science education and is aimed at middle and secondary schools. SS&C defines itself in terms of sequencing and spacing of science concepts and topics, while Project 2061 is defined in terms of learning goals. SS&C is a relatively short-term restructuring designed to induce long-term change; Project 2061 is a long-term reform that encompasses blueprints of teacher education, assessment, policy and other issues. SS&C restructures the curriculum so that students study a science subject area for several hours each week. The concepts of science are covered over several years at progressively higher levels of abstraction. Project 2061, by contrast, will provide alternative models for curriculum restructuring. Subjects will be studied in parallel arrangement with little overlap, integrated by issues or phenomena, or formed in a mosaic held together by organizing principles. Schools may replicate SS&C instructional materials, but Project 2061 has designed a set of reform tools that allow districts to develop their own curricula.

SS&C. In implementing its SS&C program the National Science Teachers Association has used funding from the NSF, the U. S. Department of Education, and state agencies to set up pilot sites in Alaska, California, Iowa, North Carolina, Puerto Rico, and Houston, Texas. Each site develops its own implementation and interpretation of the program (NSTA, 1993).

Sponsored by Baylor College of Medicine, a nonprofit medical institution, the Houston SS&C is administered by Baylor and the Houston Independent School District, the NSTA, the NSF, and the U. S. Department of Education. This SS&C site focuses on the entire school community including teachers, administrators, parents, students, and local leaders. A teacher newsletter and a parent newsletter in both Spanish and English are designed to further this concept of community (Houston SS&C, n.d.).

The core of the classroom component is a series of blocks that organize the program's approach to the curriculum. These blocks are sets of interdisciplinary activities and experiments that come in a logical sequence and are related thematically to several science concepts. Local SS&C staff, working with local scientists and science teachers, have developed the blocks from existing materials. These adaptations are then reviewed by local teachers, field tested, and revised. Blocks may be purchased; Environment, Floating and Sinking, Earth and Sky, Hot Stuff, Human Physiology, Inventions, Animal Behavior, and Hidden Structures are currently available (Baylor College of Medicine, 1993).

The program is also developing a prototype performance-based assessment set up on compact disc. Developed for grades 7 through 12, the assessment tools will be pilot-tested at the Houston SS&C site and will include a series of science test items. The Houston project reached about 28,000 students in 1993 and served 38 middle and alternative schools. The Houston SS&C plans to expand to twelfth grade and to other localities. Already satellite sites exist in Lafayette, Louisiana, the South Texas ISD (in the Texas Rio Grande Valley), and the Catholic Diocese of Houston (Houston SS&C, n.d.). The Houston SS&C has received Eisenhower funds through September 1994 (Wilt & Schmieder, 1991).

About 225 California secondary schools are restructuring their science curriculum as part of SS&C. About 90 percent of the SS&C schools have a minority group enrollment of at least one-third; in 20 of the high schools more than three-fourths of the enrollment comes from minority groups. The schools are organized into ten regions that share networking and teacher inservice training. These schools have brought about statewide changes in testing, credentialing, preservice, and university admissions requirements. In the first phase of the California project, each school devised its own approach to designing material. In the second phase a "greater commonalty between programs" is to be achieved by a statewide assessment system. A wide variety of assessment instruments will be used to coordinate science instruction (NSTA, 1993).

In Puerto Rico the SS&C program began with seventh-graders in four pilot schools; the program has expanded to the eighth grade and is now in eight schools. Materials are developed locally by teams that include a university scientist, a science educator, and science teachers. A parallel group of university mathematics educators and mathematics teachers is developing a new curriculum based on the NCTM *Standards*. Both science and mathematics teachers receive intensive four-week summer training and year-round in-service training. Joint sessions are devoted to connecting and integrating science and mathematics. The Puerto Rico project is producing materials in Spanish and expects to distribute these materials to other Hispanic populations.

Project 2061. The goal of Project 2061 is scientific literacy for all school children. The natural and social sciences, mathematics, technology, and engineering are integrated, so that a common core of learning, rather than knowledge of individual disciplines, is emphasized. Project 2061 also emphasizes acquiring lasting knowledge and skills.

Project 2061 was the sponsoring force behind the publication of *Science for All Americans* (Rutherford & Ahlgren, 1990), a major force in the reform movement. In 1993 *Benchmarks for Scientific Literacy* followed. *Benchmarks* sets out descriptions of what students should know in various areas by grades 2, 5, 8, and 12. These descriptions and goals, however, are deliberately vague, since districts, schools, and individual teachers should be able to use the *Benchmarks* in useful and meaningful ways. A later phase of Project 2061 will involve scientific societies, professional organizations, and other interested groups in collaborations to develop instructional practices based on the descriptions.

Project 2061 involved five sites to develop and test the material in *Benchmarks*. These sites originally included San Diego and San Francisco in California, three counties in rural Georgia, four predominately Hispanic school districts in San Antonio, Texas, and sites in MacFarland, Wisconsin, and Philadelphia, Pennsylvania. Since a major goal of Project 2061 is involving females, students from minority groups and lower socio-economic levels, and rural students in science and mathematics education, the program chose design sites that reflect diverse student populations. Although the teams were not to create curriculum models designed for each group, the models they produced are assumed to meet the needs of each group. Each site had a team representing different grades, function, and disciplines involved in designing goals and descriptions for science education. This work was then incorporated into the *Benchmarks* (AAAS, 1991).

At the Texas site a curriculum model called the Designed World Model was developed. Using a design perspective, this model organized six areas of knowledge into an interdisciplinary curriculum involving six clusters: information processing and communication, materials and manufacturing, health, energy, transportation, and agriculture. Cognitive and age-appropriate learning experiences, performance-based assessment, diverse teaching methods, and infusion of advanced technology were included in the clusters at all levels (Texas Project 2061, n.d.).

Equity 2000. Equity 2000 is aimed at increasing enrollment in algebra classes. Sponsored by the College Board in six school districts throughout the country, the effort restructures mathematics programs to eliminate tracking and claims success in enrolling eighth and ninth graders in college-preparatory mathematics classes. Equity 2000 programs also try to change the attitudes of teachers and counselors regarding students' capacity to learn algebra. Currently, Equity 2000 is active in 12 school districts across the country. It involves 600 schools, 2,100 mathematics teachers, and 250 guidance counselors. One Equity 2000 site is Fort Worth, Texas, which in 1991 had a student population that was 35 percent Anglo, 35 percent African American, and 25 percent Hispanic (College Board, 1993).

Fort Worth began its program in 1990 and since that time enrollment in algebra classes has risen by 36 percent; in 1990–1991 enrollment in algebra classes in the district was 3,415 among eighth-graders and ninth-graders and in 1992–1993 it was 4,562 (Licitra, 1994). Enrollment of African Americans in such classes increased by

40 percent and Hispanic enrollment increased by 60 percent. Among Hispanic males enrollment has increased 74 percent (College Board, 1993). Fort Worth started the program a year before the other sites and remains the project's "most advanced" site (Licitra, 1994).

The other five districts involved in Equity 2000 are Nashville, Tennessee; Milwaukee, Wisconsin; Prince George's County, Maryland; Providence, Rhode Island; and San Jose, California. Between the 1990–1991 and 1992–1993 school years, African-American enrollment in ninth-grade algebra increased from 38.5 percent to 42.2 percent in Prince George's County and from 34 percent to 40 percent in Nashville. In Milwaukee the percentages of both passing grades and top marks increased but enrollment increases were small. The chairman of the San Jose consortium board has said that his district wants to eliminate lower-level science courses and to try the same approach in other disciplines, including English (Licitra, 1994).

NCRMSE. Some projects focus on general restructuring of a subject area rather than changing classroom procedures. The work of the National Center for Research in Mathematical Sciences Education (NCRMSE) is an example. Algebra has been used in this country as a filter that allows children into, or keeps them out of, advanced mathematics courses. Students are expected to master arithmetic skills in the earlier grades before they are introduced to algebra. Performance in algebra is considered by teachers, parents, counselors, and college admissions officers to be an indicator of ability to succeed in college-preparatory mathematics courses and to pursue a mathematics-related career. Algebra is, thus, a road block in the U.S. mathematics curriculum. Other countries, however, treat algebra in a different way. Most industrialized countries introduce algebraic concepts at a much earlier age and integrate and connect them with other mathematics contents. In Japan, for instance, algebraic concepts are introduced as early as third grade (NCRMSE 1993b).

With funding from the U. S. Department of Education, NCRMSE, located at the University of Wisconsin, Madison, is developing a research base for the reform of mathematics teaching. Two principles have emerged from their work: Mathematics teaching is more effective when it builds on a student's existing knowledge and, second, assessment of student thinking within the context of daily instruction gives teachers some evidence of that knowledge. Learning with understanding (as opposed to learning by rote) is intimately linked with assessment practices. Rote learning has traditionally been associated with testing isolated skills, while assessment of learning with understanding tries to observe the student's application of existing knowledge to new situations. Different students may approach problem solving with different, but equally correct, solutions and procedures (NCRMSE, 1993a).

According to NCRMSE, instructional programs that foster learning with understanding have three elements in common:

Students are engaged in **sense-making** at all times.
Learning is seen as **problem-solving.**
Alternative problem-solving activities are encouraged.

Members of a NCRMSE working group on the learning and teaching of algebra, headed by James Kaput, believe that algebraic reasoning can be improved for all students if the algebra curriculum is reorganized around the concept of function with an emphasis on creating, understanding, and applying quantitative relationships. For almost a century, mathematicians have been urging that the algebra curriculum be revised to emphasize function, but the change has not been made. Now, the use of computers and new forms of software renews the need for such a change and also makes it more probable.

A second NCRMSE working group focuses on developing a reformed mathematics curriculum and the tools needed to teach it. Under the leadership of Judah L. Schwartz of the Harvard Educational Technology Center, this group is training core groups of teachers to change the way they teach the subject and the language they use in explaining algebra. The teachers were exposed to computer technologies that can enhance the graphical and symbolic representations of algebraic concepts. The data and information developed by this working group will not be finally analyzed until late in 1994, but preliminary results indicate the teachers who volunteered to learn these new ways to teach algebra did find the curriculum to be learnable and received strong support in their changes from their administrators. Often, however, they met with skepticism, if not hostility, from their teaching colleagues (NCRMSE, 1993b).

Regional consortia. Ten regional consortia—of which SEDL's SCIMAST is one—provide technical assistance and information to programs that focus on equity in science and mathematics education. Staff at the consortia offer workshops and other professional development activities that model effective teaching and assessment practices. Housed in the ten regional educational laboratories, the consortia support regional, state, and local reform initiatives for statewide systemic reform in mathematics and science education.

State-based Systemic Programs

Poor schools may not be able to take advantage of district or school-located reforms. Systemic approaches can help ensure that curriculum and instruction changes will be implemented statewide. Some states have instituted their own statewide programs. The National Science Foundation has funded many states in their attempts at systemic reform.

If educational change is based in the individual school or classroom, poor schools may not be able to take advantage of reforms. Districts and schools with many poor or minority students do not have discretionary funds to follow such paths and are more bound up in daily problems that drain administrative, teacher, student, and parent resources and abilities (Consortium for Policy Research in Education, n.d.). A strategy for statewide change ensures that schools and districts will be more or less equal in sharing changes in curriculum and instruction: "Unless curricular reforms are buttressed by a coherent state system that links teacher training, teacher certification, the curriculum and testing together into a structure within which we can legitimately hold schools accountable, we will surely enlarge the differences that continue to exist between the quality of instruction available to rich and poor, minority and majority students" (Consortium for Policy Research in Education, n.d.).

Systemic change requires both centralization (for example, the state sets certain goals for education) and decentralization (local districts will decide how to change curriculum to meet these goals) (Clune, 1991). Centralization is required because teachers and schools often lack the ability to implement new ideas. While a state may set goals, "an effective delivery system" will use local and regional teachers and administrators to spread the goals' ideas and content. "A teacher who attends a workshop on a new approach to mathematics will not change math instruction in the school unless the workshop process is replicated among the rest of the math teachers in the school" (Clune, 1991).

Several states have developed models of systemic reform. South Carolina, for example, adopted various goals including gains in standardized test scores and college entrance rates, more academic courses offered and taken, higher graduation rates, greater teacher satisfaction, and others (Clune, 1991). Grass roots political movements and state policymakers supported these changes. This political support ensured that funding for the reforms was protected; public reporting on the goals helped keep the project coherent; and limited incentives and regulatory waivers rewarded progress in individual schools. The large-scale reform in South Carolina appears to be successful, but, again, little or no research has been published on this experiment (Clune, 1991).

Roots and Wings. Roots and Wings is a state-level school restructuring program designed by researchers from Johns Hopkins University, local teachers and administrators, and the Maryland Department of Education. An integrated thematic approach to science education, the project has won two grants from the New American Schools Development Corporation, a nonprofit organization of businesses that underwrites innovative schools. Organizers and supporters assume that the project will positively affect minority and female students (*Education Weekly*, 9 June 1993).

Thematic units are produced for appropriate class levels. These units use local materials and concepts to integrate science, mathematics, history, social studies and other subjects. Daily-life materials and events are incorporated into the curriculum. The changes of this pilot project will spiral through the school systems of the state, but, to date, no research is available to confirm the positive effects that this program is supposed to cause (*Education Week*, 4 August 1993).

Statewide Systemic Initiatives (SSI). The National Science Foundation (NSF) originally funded Statewide Systemic Initiatives (SSI) in 26 states (now 25) (*Education Week*, 13 April 1994). The basic idea behind SSI awards is that mathematics and science education can be improved for all children only if isolated reform efforts are replaced by reforms that affect the entire education system (SRI, 1993). The NSF has left a great deal of latitude for states in implementing their reforms and different states have followed divergent paths. South Dakota, for instance, has used the funding to supplement their efforts at implementing new assessments.

SSI explicitly calls for providing equity in science and mathematics education for females and children from minority groups or poor families. Connecticut, Michigan, and California have concentrated their SSI money on serving underrepresented students. Montana is using part of its SSI money to develop a four-year science and mathematics curriculum that will eliminate tracking. Students who had previously done poorly in these subjects will have access to the same curriculum as other students. The state expects that poor achievers will be more interested in the nontraditional emphases of its curriculum, such as the use of technology and daily applications (SRI, 1993).

The Louisiana Systemic Initiatives Program (LaSIP) is developing new curriculum frameworks and has set up review teams to ensure that equity concerns are addressed. LaSIP is also developing a strategic plan on equity. In New Mexico the Statewide Systemic Initiative in Mathematics and Science Education (SIMSE) has set as a major goal transcending "ethnically related gaps in mathematics and science achievement" (SRI, 1993, p. II.89). The Texas SSI and most other such programs share in the idea that systemic reform requires equity in allocation of resources and instruction (Texas Governor's Office, 1993).

Some observers, however, believe that systemic reform advocates "overestimate the ability of centralized accountability and instructional guidance to bring about change in local classrooms" (O'Neil, 1993, p. 11). The NSF money available for each state—up to $10 million over five years—is also not adequate for carrying out in-depth reforms. Advocates of SSI believe that "'tuning up' the system will help all schools improve—even the bottom third of schools that proved impervious to top-down state reforms" in the 1980s (O'Neil, 1993, p. 11).

CHAPTER 3.3 Localized Reform

Throughout the country individual schools and districts are making changes in their curriculum, instruction, and structure that are at least purported to be aimed at improving equity issues.

Without being part of specific programs many districts and schools have experimented with changes that are designed to improve educational equity. Often these reforms include changes in assessment; experiments with magnet schools, vouchers, and other forms of school choice; technological improvements; and similar locally based reforms. The effects of many of these approaches have not been researched or extensively documented.

Changes in Assessments

Changing classroom procedures calls for assessments that more accurately measure students' understanding of material rather than their ability to memorize. Performance assessment, portfolio assessment, enhanced multiple-choice questions, two-staged tests, and others are among the new forms of "authentic assessment" being tried locally.

For a teacher to assess student learning under the changed circumstances envisioned by reformers, according to NCRMSE, the student will have to describe and explain the strategies used to solve a problem. Such discussions will fulfill several functions:

Students will be forced to use **procedures they understand** if they are to explain their strategies to the teacher.

Students will have to **reflect** on the procedures to explain them.

As students explain their procedures they can **learn from each other.**

The teacher can show students that **alternative strategies are valued.**

Assessment forms and procedures will have to change along with other aspects of the science and mathematics classroom. Concern about standardized tests has led to the development of "new kinds of testing measures based on entire performances," called "authentic assessment" (Zessoules and Gardner, 1991, pp. 47-71). In its present stage authentic assessment is made up chiefly of portfolios and performance-based tests. An example is Texas Assessment of Academic Skills (TAAS) for grades 4 through 8. Optional in 1994, the authentic assessment for grade 8 involved students working individually to design and build two boats from aluminum foil. Students then tested each boat by finding the number of washers each would hold before sinking. Students then compared their two designs and, using what they had learned, modified their best design to build a third boat. In scoring the task, the teacher can assess the problem-solving ability, understanding, and learning of each student. By early 1993, 19 states had begun to use alternative assessment in mathematics to bring their tests into synchronization with the NCTM *Standards* (Romberg, 1993).

The NCSESA supports science assessments that accommodate the needs of all students and avoid "language advantageous to any groups" (NCSESA, 1994, p. 7). In addition, assessment must allow for ethnic and gender differences. NCTM advocates tests that are integral to and improve learning, allow students to show what they do know rather than what they do not know, allow for the operation of both higher-order and lower-order thinking, are not controlled by the need for quantitative or objective scoring, and are practical to administer (NCTM, 1989).

Three obstacles may limit a teacher's ability to implement innovative assessments: school or district grading requirements, parental expectations, and time constraints. If the teacher can keep assessment for learning separate from assessment for accountability, the curriculum may be freed from the tyranny of standardized tests and evidence of student growth can be collected during instruction and from multiple sources.

W. Doyle has argued that "the reward structure" within the classroom affects "other instructional variables" (cited in Tobin, Kahle, and Fraser, 1990, p. 9). Students value that which is graded. When teachers use tests to motivate performance, students will focus on content identified as being "on the test." Classroom processes will revert to emphasizing recall of facts and applications to solve formulaic test questions (Tobin, Kahle, and Fraser, 1990). If alternative assessments, such as journal writing and group work, do not receive a grade, students will lessen their efforts on them to concentrate on work that will be graded.

Parents may distrust mathematics programs and assessments that do not resemble those they remember. If alternative assessment procedures are to be implemented successfully, parents must be made aware of the rationale for their use, the new forms the assessments will take, and the different kinds of information that can be obtained from a variety of assessments.

The third obstacle—time—limits the collection and interpretation strategies that teachers can use. With little or no time for reflection, teachers struggle to develop, administer, and review performance tasks and scoring criteria (NCRMSE, 1993a).

As of January 1991, 40 states had, or were planning to use, at the statewide level such alternative assessment forms as performance assessment, portfolio assessment, or enhanced multiple-choice.

Eight state assessment programs use one or more of these three alternative forms in assessing science at the secondary school level and thirteen use them to assess mathematics.

In the southwestern region, New Mexico and Texas use alternative assessment at the statewide level. Once a year New Mexico gives an enhanced-multiple-choice-question test of science achievement in grades 3 and 10 through 12; no alternative assessments are used in mathematics. The results of the science assessment are used to monitor student progress and to make decisions about promotion and district curriculum development. The results are not compiled in statewide reports, and do not influence curriculum at the state level, state policymaking, or school accountability (Council of Chief State School Officers, 1991). The New Mexico High School Competency exam contains an essay component that may focus on science. In 1994–1995 a portfolio assessment option will supplement the competency exam.

Several districts, schools, and individual educators in the Southwest have used alternative assessments of varying levels of complexity. In Texas, Project ABCD (Alternative Blueprint for Curriculum Development) has developed an activity-driven curriculum for grades K–12. Sponsored by the Texas Association for Supervision and Curriculum Development, Project ABCD has objectives for each grade or course, and assessments are coordinated with these objectives either individually or as clusters. Most of these assessments are nontraditional and require responses that run the gamut of written, oral, visual, and physical. Responses can be structured, open-response, or open-ended. Students can grade their own work or it can be graded by peers or the teacher. Written by teachers, the program and its assessments are designed to meet the needs of students regardless of gender, race, economic status, or previous performance (Laboratory Network Program, 1993).

In Wichita Falls, Texas, the independent school district and Midwestern State University have collaborated in the use of new technologies to integrate instruction and assessment. Performance tasks have been designed using Macintosh computers and the videodisk series “Windows in Science.” A performance task called “Fox Rot,” presents students with five photographs of a decomposing fox body. They must place the pictures in chronological order and explain their reasoning for that order. Two other tasks— “Are You Listening?” and “Mitosis”—are being developed. “Are You Listening?” is an interactive program to convey and assess concepts of pitch and intensity; “Mitosis” simultaneously instructs and assesses student understanding of cell division (Laboratory Network Program, 1993).

Sabine Parish in Louisiana uses portfolios to support site-based decision making in grades K-6. No single assessment is used for an objective; rather teachers use a variety of techniques that test students according to their individual needs and learning styles. The portfolios contain teacher observations and students' representative work. The portfolio contains a checklist and inventory of curriculum skills the student is expected to master, work samples, teacher notes, student self-evaluation, notes from parental conferences, and referral records. The mathematics portion of the portfolio is based on the NCTM *Standards* (Laboratory Network Program, 1993).

Most alternative assessments are still being tested. The research base that will show the validity of these practices is still being developed. Many experienced educators, however, believe that alternative assessments are the best tools for finding out what students know and meeting equity goals at the same time. Alternative assessments meet both of these goals because they "give all groups a fair chance to demonstrate what they know" (Malcolm, 1991, p. 324). Alternative assessment does not make all results the same but it does take into account the fact that each child has different strengths.

Magnet Schools, Choice, and Vouchers

Whether magnet schools, school choice programs, and vouchers are exclusionary or inclusionary is still a matter of controversy in research, policy making, and political life.

Magnet schools, choice among public schools, and vouchers that allow parents to send their children to private as well as public schools have become politically important approaches, especially after the Ronald Reagan and George Bush administrations strongly advocated vouchers as a solution to the problems of public schools. Some argue that these approaches can improve schooling for all students; others see them as yet another tool for discrimination. Virtually no data are available to substantiate either claim. While the Reagan and Bush administrations did not succeed in introducing choice and vouchers nationally, some school districts and states have considered implementing such plans and many have had magnet schools for several years.

The academic difference between magnet and nonmagnet schools is often no greater than the differences between individual neighborhood schools since "test scores and the social class of students differ markedly among neighborhood schools" (Metz, 1990, p. 113). Mary Metz believes that magnet schools create neither greater nor lesser inequality but that access to good schooling may be more open in magnet schools than it is in neighborhood schools. Magnet schools can be desegregated and can serve as a diverse area where races and classes can be brought together. Still, she also believes that "to deny magnet schools' potential for elitism is naive" (Metz, 1990, 114).

Jonathan Kozol (1992) holds that the most important factor in getting into a good magnet school is the social class and education of the child's parents. "The system rests on the initiative of parents. The poorest parents...lack the information access and the skills of navigation in an often hostile and intimidating situation to channel their children to the better schools, obtain the applications, and...help them to get ready for the necessary tests and then persuade their elementary schools to recommend them" (p. 60).

Gary Orfield (1990), director of the Harvard Project on School Desegregation, believes that magnet schools will always be based on exclusion. While this exclusionary process will enable these schools to improve their accountability in the form of test scores, it will also lower morale in the schools that are not magnets. He argues that magnet schools will always appear to be successful because "any kind of selective admissions will produce a school with higher test scores" (p. 119).

In contrast David A. Bennett (1990), who worked with the school choice program in Milwaukee and is the founder of Education Alternatives Inc., believes that magnet schools can be designed to be inclusive. Milwaukee, he says, pioneered a desegregation plan that relied on choice and magnet schools. This approach, according to Bennett, produced a stable desegregation program because school populations could be adjusted each year—unlike desegregation plans that depend on the redrawing of district boundaries or the reorganization of grade levels. Magnet schools were an essential part of this desegregation plan because they offered a wide variety of programs designed for students with differing abilities and interests. Bennett sees magnet schools and school choice as offering the possibility for diversification within public education and, thus, as challenging "the continued existence of private schools" (p. 150).

In a Rand report, Paul T. Hill, Gail E. Foster, and Tamar Gendler (1990) studied selected New York City high schools and compared comprehensive, magnet, and Catholic high schools in their ability to motivate and retain low-income and minority students. Their study found that the magnet and Catholic schools did a better job of educating students from minority groups and lower socio-economic backgrounds than did the comprehensive schools. They found that this success did not result from small school size, the ability to choose students that will attend the school, the unique features of religious education, a regimented student body, or the wearing of school uniforms, as some have suggested. The researchers used the term *focus school* to categorize successful magnet and religious schools and identified three characteristics these schools shared: Focus schools do not have to deal with "internal and external barriers to invention and initiative" (p. 35), have "clear uncomplicated missions" that are concerned with the students' experiences and what the school intends to give them, and have strong organizations that pursue the school's mission and manage relations with outside parties.

School choice advocates argue that these programs give more students a chance to attend successful schools and improve bad schools through competition. Competition, they argue, will improve schools. School systems will then regain the confidence of families that left the public school system. Public education as a whole will be improved (U. S. Department of Education, 1989). Advocates see parental choice as capable, on its own, of improving student performance through building community and a sense of mission (Chubb & Moe, 1990).

Many educators, legislators, and concerned citizens, however, fear school choice as a stalking horse for voucher programs or school consolidation or as a means to continue "denial of equal access and quality education for African-American students" (Trent, 1992, p. 293). William H. Clune has pointed out that "the political path of least resistance" for implementing school choice would be to allow students or parents to choose their schoolmates. This process, he believes, would encourage "severe stratification of enrollments by race and class." Political and financial support of public education would erode as the more well-off moved to "supplementary contributions" (Clune, 1991, p. 13).

Classroom Dialogues

Teachers who create classroom dialogue enable students to become actively involved in their own learning. In a dialogue both teachers and students are true participants and each learns from the exchange. Research has indicated that children from poor and minority backgrounds may especially benefit from such methods.

Teachers' beliefs, the metaphors by which they structure their ideas of teaching and subject content, and their knowledge of that content influence the learning of their students (Tobin, Kahle, & Fraser, 1990). Most science teachers appear to have "a cultural transmission view" of teaching (Pope & Keen, 1981, cited in Tobin, Kahle, & Fraser, 1990, p. 34) in which they transmit "truth" by iteration to students. In a metaphorical sense these teachers see knowledge as "a fluid entity" that they can transfer to their students. By contrast, a constructivist view of teaching sees knowledge as a change in thinking patterns brought about by "experiential problem-solving situations" (Tobin, Kahle, & Fraser, 1990, p. 34).

Interactive teaching. What some have called interactive teaching is built on a framework of dialogue, a "dynamic social process" in which teachers discover, through questioning and listening, what students know and do not know in order to help them advance their learning (A. Anderson, 1991, p. 211). Drawing on the work of many others, Alonzo B. Anderson compiled a list of essential knowledge and abilities for teachers who are trying to create a constructivist learning environment.

According to Anderson, constructivist teachers should be able to

- **create tasks** that combine instructional objectives and emphasize new skills and concepts;
- **assess** students so that instruction is always aimed just a little above the student's ability level;
- **nurture** students' internal motivation by linking classroom work to meaningful goals;
- **model, question, and directly explain** so that the purpose and execution of tasks are clear to students;
- **respect** divergent responses from the students;
- **praise, acknowledge and encourage** students specifically;
- **restate correct responses** so that important information is apparent;
- create **classroom dialogue** and bring students into it;
- create tasks that **actively involve students** with the teacher and with other students;
- use **performance evaluations** to adjust each child's classroom support;
- allow students to **assert independent control** over their tasks.

In such classrooms, teachers need to think about how to organize effective discussion groups and how to help children reach a general explanation or agree not to reach such an explanation. How the teacher will know when a topic is finished and what each topic might lead to are also questions each teacher must think about ahead of time—although some teachers may not feel constrained to reach a consensus on each problem (Easley, 1990).

In a dynamic learning environment teachers will not be the "only sources and validators of knowledge and insight" (Ball, 1991, p. 71). Other students should also be able to question the claims of their peers, to examine ideas behind statements and observations, and to comment on other students' work in a constructive way. If teachers encourage such abilities, students will become more confident of their abilities to judge and monitor their own thinking.

A teacher who creates an interactive classroom soon comes to focus on the "learners rather than the discipline" (Tobin, Tippins, & Gallard, 1994, p. 49). If, instead of seeing themselves as the transmitters of content, teachers see themselves as the mediators or facilitators of the students' learning, they must monitor that learning daily and must figure out how to channel student activities and thinking productively. Dialogue between teacher and student and between student and student helps the teacher achieve these goals.

When Kenneth Tobin and his associates observed exemplary science teachers who used these methods, they found that the teachers "actively monitored students' behavior by moving around the room and speaking with individuals from time to time" (Tobin, Tippins, & Gallard, 1994, p. 53). These classes work and are not disorderly because students must cooperate with each other and the teacher; students learn to work together and to seek help not only from the teacher but also from peers.

The truly interactive teacher allows students to formulate their own questions and answers and to form their knowledge from the intersection of their existing knowledge and what they accumulate in class. Constance Kamii, using the work of Bärbel Inhelder and others, has observed that when children are confronted with conflicting ideas in the logico-mathematical realm, they can construct an answer that they will find more satisfying without direct teaching from an adult. A Socratic question or the articulation of conflicting viewpoints will lead a child to his or her next deduction. "Children's 'wrong' ideas are not errors to be eliminated but relationships to be coordinated better" so the child may reach the next level of understanding (Kamii, 1985, p. 31). If, for example, several children have deduced differing answers to a simple arithmetic problem, the interactive teacher does not reveal which child has the correct answer but encourages a dialogue among the children. As each child defends her or his solution an understanding of the best explanation should emerge. "If a child thinks that 8 + 5 = 12, he should be encouraged to defend his idea until *he* decides that another solution is better. It is important to encourage children to have their own opinions and to let *them* decide when another idea is better. Wrong ideas have to be modified by the child" (Kamii, 1985, p. 36).

Barbara Means and Michael S. Knapp have identified interactive teaching as an important component in teaching children from minority groups and from low socio-economic levels (Means & Knapp, 1991). This instructional method is effective, however, only when both "parties are full-fledged participants, both with significant influence on the nature of the exchange" (p. 288). In these circumstances, students can learn "advanced skills" from the beginning of their education. All students, but especially "educationally disadvantaged" students, respond better to the contextualization that dialogue confers on learning. When the teacher treats divergent opinions seriously and all engage together in seeking the best answer, poor students, students from minority groups, and female students should feel that their scientific and mathematical observations are as valuable as those of white male students.

Cognitively Guided Instruction. Cognitively Guided Instruction (CGI) is a multi-year program with National Science Foundation funding. Its goal is to provide elementary school teachers with information from cognitive science research regarding children's mathematics learning. CGI emphasizes teachers' knowledge of their individual students' thinking processes. This awareness of student thinking is obtained by engaging students in dialogues that reveal their thinking about mathematics. Teachers pose word problems and encourage "the use of multiple strategies to solve" these problems (Peterson, Fennema, &

Carpenter, 1991, p. 96). Teachers then use their knowledge of cognitive science research and their understanding of their students' thinking to make classroom decisions. CGI training does not offer teachers specific practices or behaviors. Rather, it emphasizes recognizing and encouraging multiple solutions to problems, focusing on problem solving, and achieving an expansive view of children's mathematical knowledge by using dialogue to assess children's abilities in the classroom.

In a 1990 dissertation A. Villasenor reported his work with CGI in first-grade classrooms in Milwaukee. He tested the method in 12 classrooms with between 57.4 percent and 98.4 percent populations from minority groups—either Hispanic or African American (Secada, 1992). Teachers from these schools were given a twenty-hour workshop that focused on CGI readings and materials and was spread out over one week. During the school year these teachers met one Saturday a month to discuss CGI ideas. A control group of teachers from matched classrooms received training only in problem solving in October and January (Peterson, Fennema, & Carpenter, 1991). In the classroom the CGI teachers "focused their attention on children's thought processes and engaged them in substantive conversation" (Secada, 1992, p. 650); the control teachers used more drill and practice. Various measurements, including scores on tests administered by Villasenor, indicated that when CGI teachers taught students from minority groups they outperformed the students taught by the control teachers. Villasenor's results led Peterson, Fennema, and Carpenter (1991, p. 99) to conclude that CGI can be an effective tool for teachers of minority and poor students:

> When teachers begin listening to and talking with their children, they come to realize how much more their children know than they had recognized previously....Teachers can achieve the goals of compensatory mathematics education by focusing on and using their children's mathematical knowledge and thinking in their classroom teaching.

Improved Technology and Materials

Many observers have pointed out that new instructional technologies have great potential for teaching traditionally underrepresented students. Finance may be a difficulty for chronically underbudgeted schools, however, and little research has been done to test the usefulness of technology-based education. Textbooks will continue to be important tools in U.S. classrooms. They can be modified, however, to be better teaching tools.

Technology. Improved technology has the potential to open new educational horizons for all students and especially for children from traditionally underrepresented groups. Poor inner-city and rural schools, however, often lack any way to use technological materials in an efficient, useful, and appropriate manner, much less the financial means to acquire them. Educational technology must be used well if it is to be useful in solving teaching problems, especially among students who have been labeled at-risk. Teachers in schools with constrained budgets often have little or no training in the use of learning technology. Computer equipment in such schools is frequently made up of out-of-date machines cast-off from area industries and businesses that no longer need or want the machines. If an investment in computers is to be useful to a school, the investment in software and training must be roughly equal—if not greater (Branscum, 1992).

Other problems may arise from teachers' use of the machines. Teachers in financially strapped schools tend to use computer games as rewards after students have spent time in drills and rote learning. In this way students come to see technology as part of school problems rather than as a release or a new, more approachable, learning tool. In some schools with few resources teachers use the computer as a reward for well-behaved students, even though most research indicates that low-achieving students respond most markedly to computers (Alexander-Kasparik, 1993).

If teachers and schools understand how to use technology, classroom machines can tremendously affect the learning of poor students and students from minority groups. As Allan Collins (1991) has pointed out, computers can be useful tools in setting up a constructivist and cooperative classroom. Carl F. Berger and his coworkers (1994) have warned that computer-based instruction can become stuck at a drill and rote learning level rather than reaching all of its potentials, including the ability to engage previously uninterested or left-out students in their schoolwork. "The future of instructional technology lies with the ability to use multimedia to provide supporting instruction experiences for a wide variety of students with diverse backgrounds not only of culture but also of learning styles" (Berger et al., 1994, p. 476).

In Apple Classroom of Tomorrow (ACOT) schools, time spent on teacher-led activities decreased from 70 percent of class time to 10 percent with the use of microcomputers. Teachers in these classes used the time released from lecturing and dealing with whole-class activities to spend more time with individual students and to develop better awareness of each student's understanding (Collins, 1991). In computer-rich classrooms teachers begin interacting less with the better students and more with weaker students. Teachers who might hesitate to call on a low-achieving student in class may find it easier to help that same student work out his or her own problems at a computer (Schofield & Verban, 1988). Most research on computer-based education, however, has focused on high-achieving students rather than low achievers (Berger et al., 1994).

The pitfalls of using computer-based instruction uncritically are illustrated by the work of Reiser, who identified three interactive learning environments. **Tutored learning** monitors student work and intervenes when the students make mistakes; students are given the information necessary to correct their errors. **Discovery learning with assigned problems** gives problems to students, as does a tutoring program, but allows them to make and check their own hypotheses and does not intervene when they make mistakes. When students have completed their work they can find out whether or not it has satisfied the problem. **Discovery learning without assigned problems** has a list of optional problems from which the students can make selections. Students have complete control over the learning experience and receive no guidance when they make mistakes or when they complete the work. Students have to request information about their progress. Discovery learning situations offered high-achieving students great gains and offered low-achieving students great losses (Reiser et al., 1993). Unsupervised, even high achievers can develop misconceptions that are never cleared up. Teachers have to be aware of the differences in programs and in students and have to decide if and when to intervene in a student's work (Reiser et al., 1993).

Computers offer great opportunities for students to develop critical and original thought, but teachers will have to be aware of the differences among computers, their programs, and their uses. Teachers have to be aware of different ways that students learn and how computers can be used to facilitate learning in each situation. Computers can especially help to open up classrooms to diverse methods of teaching for individual students that would be impossible in traditional classrooms. "We can imagine a scenario in which students are truly empowered to learn, mediated instruction supports the instructor..., and technology is an answer (not the answer) to providing instruction to a diverse range of students with varying learning needs (Berger et al., 1994, p. 487).

One example of such technology is the Adventures of Jasper Woodbury series produced for middle school children by the Learning Technology Center of Vanderbilt University (1992) and Optical Data Corporation. This series presents a believable challenge played out with interesting characters. Students must use problem-solving and mathematics skills to solve the challenge, which consists of various subproblems that have to be solved to answer the overall problem. All data needed for the solution are in the video. If the challenge is to be answered expeditiously, students must share their knowledge and strategies.

Textbooks. Materials are important to any improvements in science and mathematics teaching. Teachers need materials that they understand and that help them convey a deep understanding of the sense and meaning of the subject matter. Although textbooks tend not to be the best answer to the needs of the real classroom, they will probably be a staple of education for the foreseeable future. If they cannot be replaced by more useful materials, then textbooks must at least be improved in the direction of enabling more collaborative and hands-on work. Teachers must at least modify if not reject the tasks most textbooks present to them. "These 'teaching aids' support a kind of teaching that leads to rote memorization of facts and definitions, not teaching that helps students deepen their understanding of the natural world" (C. Anderson, 1991, p. 12).

Most textbooks give no idea of why scientists and mathematicians are interested in their fields or of why they pursue the knowledge they seek. As Charles Anderson has put it (1991, p. 15),

> The idea that plants use light to make their own food can be treated as a simple statement of fact; that is what most textbooks (and most science teachers) do. Used as a tool, however, this same idea can help explain many things about green plants: why they have leaves, why their leaves turn toward the sun, why they die without light, why animals depend on them and so forth.

If teachers, schools, districts, and parents begin to demand new relationships between the textbook and the student, publishers will eventually listen. Textbooks and their adoption policies are pieces of complex political and economic structures. Those who advocate reform of science and mathematics education must learn something of the complexities of these structures and how to use them. The politics of textbook adoption involves "the diverse interests of publishers, policy-makers, single-issue pressure groups, and classroom teachers" (Tobin, Tippins, & Gallard, 1994, p. 70). Reform is likely to become lost unless the quality of textbooks and the wisdom of spending state money on them becomes a matter of importance to one or more of these groups.

A hopeful indication is the fact that some states—Texas among them—now allow state funds to be used to purchase alternative curricular materials—laser discs, software, and similar items. This fact also makes clear that learning technology and classroom materials are intimately related to one of the most intractable, contentious, and public of all equity issues—school finance. Most states are now being forced to deal with inequity in financial resources in very public ways—through court cases and legislative changes.

Chapter 3.4 School Finance Equity

All states—except Hawaii where the state fully funds all education—finance their public education systems through some combination of state and local tax revenues (Walker & Kirby, 1988). In recent decades this finance structure has been challenged in the courts and the legislatures of several states. Many observers believe that reliance on the property tax to fund public education creates inequity in school finance. Local school boards and community leaders, however, often see the property tax as an important component in retaining local control of schools. Solutions to equity issues in the fiscal arena seem destined to be worked out in the courts and state legislatures and to involve contentious public debate.

The Texas Experience

For more than 20 years Texas has been dealing with the equity of school financing in the courts and the state legislature. Consolidation has emerged as the solution, although it has problems too.

Equity in the allocation of school funds is a contentious issue for states and localities. Each solution that is proposed appears to offend some group within the school community, but funding is the bedrock of equity issues and strategies. Without adequate funding, innovative teaching methods are irrelevant. How can children learn adequately in a school with toilets that are unusable? For that matter, how can students learn adequately if they are homeless and hungry?

Texas offers an example of the kinds of solutions that have been proposed throughout the nation. The state has been embroiled in court challenges and legislative attempts at remedy since Rodriguez *vs.* San Antonio Independent School District challenged the constitutionality of Texas school finance in 1971 (Walker & Thompson, 1989). While a lower federal court ruling that the finance system was unconstitutional was reversed by the U. S. Supreme Court in 1973, the feeling that the state could equalize disparities between rich and poor school districts persisted. The post-Rodriguez approaches to school finance reached a crisis in 1987 when a district court declared the existing state system of finance unconstitutional in Edgewood Independent School District *vs.* Kirby (Walker, 1988). In response to the issues raised by this case the state legislature passed Senate Bill 1 in the summer of 1990, but the finance provisions of this act were declared unconstitutional the following year. After four special sessions devoted to education and financing, the legislature had to return to the task of equitably distributing state education money (Texas Education Agency, 1991 and 1992).

In a May 1993 special election 60 percent of voters rejected a proposed constitutional amendment that would have allowed for regional sharing of local property taxes, the system state officials had come to prefer. Since the state faced a June 1 deadline before all school funds would be cut off, the legislators turned to consolidation as the only politically feasible answer. As part of the final bill, wealthy and poor districts, not always contiguous, were combined in order to create districts that have resources at about the state average. This plan had the political advantage of remedying extreme cases of financial disparities while leaving most districts untouched (*Education Week*, 12 May 1993). Many people were disgruntled with this solution, however, and the issue seems destined to continue to bedevil Texas politics. Court challenges began almost immediately.

Michigan and the End of Property Taxes

Michigan is no longer using property taxes to fund schools. This approach could eliminate disparities between rich and poor school districts, but alternative forms of funding are not popular either.

In the nationwide struggle over the proper method of funding public schools, Texas is typical of a growing number of states being forced to meet finance equity issues in the courts. Michigan took a more radical step when it banned property taxes as a method for funding public schools; the ban became effective in January 1994. The law cut property taxes for homeowners and businesses by about 65 percent, and when it went into effect the state had to come up with $5.6 billion to fill the gap. The bill that banned property taxes for education included no alternative method for collecting funds (*Education Week*, 4 August 1993).

Critics of the prohibition of property taxes called it "shamefully reckless." The Michigan Education Association and Moody's Investors Service publicly expressed skepticism about the change. The investor service noted that the credit quality of 60 local bond issues became questionable when the law passed.

When the bill passed, most people believed that the state would restore the lost funds through some combination of increases in income and sales taxes. Forced consolidation of local districts and repeal of teacher tenure were other suggestions. Cost-cutting was also suggested but, since many observers thought that Michigan schools were already underfunded, most believed the legislature would have to find replacement money for almost the entire $5.6 billion (*Education Week* , 4 August 1993).

In March 1994, however, the voters decided that they would support schools by taxing purchases rather than property. A 2-cent increase in the sales tax was passed over an alternative proposal, backed by the Michigan Education Association, that would have increased the state income tax. The proposal that passed also instituted a small property tax—6 mills against a state average of 37 mills—and raised other state taxes on cigarettes, interstate phone calls, and real estate transfers (*Education Week*, 23 March 1994). Opponents of the sales tax hold that it will not be as stable or as lucrative as the income tax. Others expressed concern over increased state control of education (*Education Week*, 9 March 1994). State officials estimated that the new plan would increase state spending on education from $9.6 billion to $10.2 billion (*Education Week*, 23 March 1994).

Federal Equalization

Some senators have suggested creating a federal fund to help states equalize the imbalance between rich and poor districts. Other public figures have suggested a federal level value-added tax to aid education.

Since the summer of 1993, Sen. Paul Wellstone (D., Minn.) and seven other senators on the Senate Labor and Human Relations Committee have hinted that they might propose creating a pool of federal funds to aid states in balancing school funding between districts. Wellstone has suggested that money could come from Chapter 1 funds of the Elementary and Secondary Education Act (ESEA) and new programs to help schools share funding (*Education Daily*, August 4, 1993). Gov. Roy Romer (D., Colo) has suggested that a national tax—such as a value-added tax—could be used to create a reservoir of monies for rectifying education inequalities among states and districts (*Education Daily*, 28 July 1993). Neither of these proposals was acted on during the 1993–1994 congressional session.

Federal and State Court Cases

Court cases since the 1960s have established a body of legal principles regarding educational finance equity. Two standards of equity have emerged: expenditure equity and fiscal neutrality.

Since the late 1960s more than three dozen court cases at federal and state levels have established basic principles concerning finance equity in public education (Walker & Kirby, 1988). Courts at all levels seem to agree on the following principles:

- Education is not a **fundamental right** protected by the federal constitution. State constitutions, however, usually have some avenue for addressing inequitable school financing.
- The state has a **fundamental interest** in education and can raise money and allocate school funds. By implication, then, all school property, funds, and taxes are actually state property, funds, and taxes.
- The **wealth of the state** as a whole should be the determining factor in the quality of a child's education rather than the wealth of the child's parents or school district.

- **Expenditure differences** between districts should be based on perceived public needs not district wealth. While the state cannot require districts to spend identical amounts of money, districts with equal needs should have equal opportunities to fund those needs.
- Districts may spend additional amounts for programs and children that require **differential treatment** (special education, compensatory programs) and states need to account for different needs in their formulas.
- So far, states have not been required to substitute other **types of taxes** for local property taxes, even though some decisions have found local property taxes to be regressive. Courts have held that state aid formulas should offset local differences in taxable wealth.
- No court has explicitly required equity in **capital outlay expenditures**, but many judicial decisions seem to imply this idea.
- No **specific equity plans** have been imposed on states yet. Courts have generally given state legislatures time to revise laws and formulas to meet required criteria.
- Through all of the legal arguments two standards of equity have emerged: **expenditure equity** and **fiscal neutrality**. Expenditure equity requires that districts spend similar amounts on each pupil; under fiscal neutrality district expenditures are to be independent of district wealth.
- While most state educational fiscal systems lack equity because of variations in property wealth between districts, low levels of state aid often add to the problem. These two problems are then compounded by district **organization** inadequacies, differences in district **efforts**, and poor or **unsound legal and financial provisions**.

Problems with school district organization are usually found in districts with small enrollment. These districts have higher costs for each pupil and face skewed taxable wealth in relation to each pupil. Consolidation can lead to greater fiscal equity, but in many states and localities consolidation is considered a threat to local control of schools and often to a locality's very existence as a community.

Lotteries and Legalized Gambling

Lotteries and various forms of legalized gambling seem like painless substitutes for taxes. As supports for education, however, they carry some grave problems. These income forms usually supplant regular school funding rather than supplementing it.

The desire to avoid raising taxes while funding schools at an equitable level has led some states to turn to lotteries and legalized gambling. These methods share attractions and problems.

According to the Educational Research Service (ERS) lottery funds are unstable and unpredictable and can result in schools' being unable to obtain needed funds. Public perceptions that lotteries are a bountiful source of monies for schools have sometimes made it difficult for schools to find needed funding in state budgets. In practice, lottery money does not supplement regular school funding but supplants it. In 1991 in the 11 states that dedicate part of their lottery profits to schools, those funds amounted to 4 percent of the states' education spending. In at least one state—Illinois—general funding for education began to decrease when money from the lottery and legalized gambling was made available for schools. Nationwide in 1991 only 40 percent of lottery proceeds was available to states for revenue substitution for all programs. About 54 percent of proceeds went to prizes and the rest to administration and operations. Lotteries are also more expensive to operate than are other forms of state revenue collecting (ERS, 1993).

The attractions of both lotteries and legalized gambling are that they seem to be relatively painless for taxpayers. "Legislators are looking for a source of funding that will not be related to their given constituency....With gambling these are always somebody else's revenue sources," according to David S. Honeyman of the University of Florida (*Education Week*, 16 March 1994, p. 16).

PART 4:

Conclusions: Transforming Learning

To reach equity in science and mathematics education, the structure of schooling in the United States will have to be transformed. Such a transformation will involve more than changes in classroom configurations or funding distribution; it will have to involve "a structural change in the ways in which...voices are incorporated" into the classroom (Wallace, 1994, p. 186). Transformation will have to involve valuing differences while inviting all to share in the whole (McLaren, 1994). This whole, however, will not be the "harmonious whole" of the melting pot, but rather a "difficult whole" that accomodates varying and sometimes contradictory realities within its totality (Murphy, 1991, p. 126). Equity will be achieved if all voices are valued and subjected equally to the same processes of critique and investigation and if instruction is structured so that each student is fully engaged in meaningful learning. Transformation is not a temporary cathartic but an ongoing emancipation that does not end (Giroux, 1981; Greene, 1978).

If instruction is to be transformed, science and mathematics teachers must move from their positions in the center of the classroom to incorporate many classroom voices. By doing so, teachers do not abdicate their responsibilities as guides to learning; rather, they use pedagogical changes to allow children to investigate with their own tools. Together, students and teacher critique their assumptions, methods, and outcomes to arrive at their results. Hands-on, collaborative, and constructivist methods will enable children to use their natural interests in the world around them to incorporate mathematics and science into their own knowledge base.

These methods, though, can be threatening to teachers who are used to total control of a classroom. Using these methods involves transformative changes for teachers in both practice and self-image. To achieve equity in the classroom teachers will have to be self-aware—to acknowledge their conceptions of students and their cultures and to know how their culture has formed their own minds. As teachers move from the center of the classroom, they have to transform themselves into lifelong learners continuously seeking knowledge of content, method, strategies, and personal relations to guide them in the future.

A real danger is that as new approaches begin to show that they can produce results, imitations will call themselves "constructivist" and become incorporated into teaching in a formulaic way. Approaches for dealing with children from "nonmainstream" cultures could become unthinking practices. Teachers could begin to deal with children in stereotypical but approved ways that reinforce manipulative practices rather than genuine learning. If stereotypical responses to children from cultures other than the teacher's own are called "culturally appropriate teaching," equity will not have been achieved. If teachers do not engage in the basic self-reflection that leads to empathy and understanding of children as individuals, their teaching will never be transformed into anything beyond ritual. True transformation of education arises from classroom respect for individuals and for the learning that is being offered.

Activities can be misnamed and passed off as constructivist. If students spend their time making Jell-O molds of dinosaurs and everyone calls the result "hands-on science" no improvement over the lecture system will have been realized. If the materials teachers use for hands-on teaching are developed by the same editors, writers, and publishers who developed the older textbooks and these producers have not transformed their own orientations, the new materials will be no more effective than the old, although they may be more fun for the children and more comprehensible for the teachers (Padian, 1993) .

Activity-centered learning can easily degenerate into "cookbook learning." Unless teachers can actively use materials with genuine understanding and can grasp the underlying meanings of the approaches they adopt, students will miss understanding as surely under an active instructional paradigm as they had under the old passive learning. Active learning is one of the important tools in bringing science and mathematics to all students, but truly active learning requires work and thought on the part of everyone concerned. The temptation to accept imitations will always be strong—especially for teachers with their constant concerns for time and accountability. Imitations of active learning will not advance equity concerns and will only perpetuate the problems of all the older systems.

Equity is an incredibly complex concern. Different people involved in equity issues have different agendas. Different people define the goals of equity in varying ways. Is reformed science education designed to prepare students for college, the work force, or a lifetime of learning and the pursuit of knowledge? Are these goals necessarily in conflict or are they congruent? If classroom teachers are to emphasize the practical, will students learn the important theories behind the facts and formulas? Can teachers learn to share the responsibility for learning with their students? If parents are to be involved in their children's education, can one assume that they will always have students' long-term interests—rather than the immediate interests of the family—at heart? If respect for local culture and gender equity clash, which goal is to be given more value? How far does respect for local culture extend? What happens to science education when it conflicts with local religious views?

Transformation will be painful for those it affects the most—teachers and students. The future of reform depends on whether or not educators—and especially classroom teachers—are motivated to accomplish the changes required of them. This motivation will, in turn, depend on such factors as "the content of the reform, the faculty's willingness and capacity for change, the strength of the school as an organization, support and training, and leadership" (Evans, 1993, p. 20). Unless all concerned agree that the proposed innovations are needed and possible, teachers will be inclined to resist changes. Both staff and institutions must be ready for change. Administrative personnel must be committed not only to the reforms themselves but also to supporting teachers as they accomplish the needed changes. Parents and community must support the schools in their transformation. To do this, they will have to be frequently and honestly informed of the changes to be made and the goals to be reached.

All the strategies designed to achieve equity will be in vain if they do not address the root causes of the symptoms that are in evidence today. Asa Hilliard (1988) maintains that "stereotyping, ignorance, and miscommunication" are only "euphemisms for the deeper problems of privilege, oppression, or inequity" (p. 39). If attempts at achieving equity in science and mathematics education are not part of strategies "to eradicate the uneven impact of privilege and oppression in education" then ultimately they will fail (p. 42). Unless the root causes are removed, the old problems of equity in education will only return in new manifestations. John Ogbu (1978) argues that "so long as caste remains the principle of social organization, no efforts to use the schools to equalize the social and occupational status of different minority and majority castes can succeed" (p. 358). For Hilliard, "it is politics, not pedagogy, that prevents school people from doing their best with all pupils" (pp. 42–43). Both acknowledge that schools cannot solve the problems of society on their own, but both also realize that schools are an integral part of any answer that will work.

At the root of the politics that Hilliard identifies as the problem is power. The "traditionally underrepresented" groups are precisely those that have lacked power in our society and continue to lack it today. "Unless the dynamics of power are addressed, unless the range and consequences of cultural capital are supported, and unless a deep vision of schools as community-based democracies of difference is engaged," no lasting changes will be achieved by reforming education techniques (Fine, 1993, p. 707). Knowledge is acquired and produced within society's power structures. Without the restructuring and rethinking of power—both in and outside of the classroom—power alone will continue to provide, as it has in the past,"the conditions for the production and acquisition of learning" (Giroux, 1993, p. 162).

When schools across the country are all dealing with the same problems—in-school violence, lack of discipline, inequality between schools, and illiteracy, not to mention a perceived lack of learning of science and mathematics—these problems cannot be the result of a local school board's actions or inaction, as Alan Ehrenhalt, executive editor of *Governing* magazine, has pointed out. The schools' problems reflect society's own problems "with literacy, violence, and inequality—with its values in general" (Ehrenhalt, 1993, p. 68). Journalists "need to stop pandering to the American people as innocent victims of government and begin talking to them candidly as co-conspirators. And they need to show some respect for the complexity of the problems they set out to solve" (p. 68).

Hilliard, Ogbu, and others locate the crux of equity problems in the larger society and its socio-economic structures. But this fact does not remove the schools from the center of the problems. While problems may originate outside of the schools, educators cannot use this fact as an excuse to absolve themselves from achieving equity in science and mathematics education. Schools cannot fall back on the inequality and society's power distribution as an excuse for their own failings. Neither can they solve their own problems in a way that will be meaningful for their students if society outside of the schools does not begin to offer rewards to those it has neglected. In schools knowledge and power relate to each other in ways that reflect the conflicts of the larger society (Giroux, 1993).

No matter what society at large does, schools must critically rethink and transform their purpose within that society (Giroux & McLaren, 1989). Schools and teaching must become institutions that do not just "value" or acknowledge difference among students but that make difference a central and defining quality of classroom life (Giroux, 1993). They must then use that quality to rebuild the relations within the classroom and the relations of the classroom to the larger world. To achieve these goals, teachers will have to adopt new teaching styles, such as those outlined here; they will have to value reflection and self-criticism. They will have to open science and mathematics classrooms to the needs and abilities of each child in the classroom with no preconceptions of who is "good" in these content areas. Most of all teachers, students, parents, and administrators must acknowledge each other's humanity and integrity. Working from that understanding, they can attempt to build classrooms free of arbitrary limitations—classrooms committed to shaping learners who value each other and their own pursuit of knowledge.

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Index of Programs

Appendix

Eisenhower National Clearinghouse and Regional Consortia

The Eisenhower National Program supports a clearinghouse and ten regional consortia that make up a network supporting systemic reform of mathematics and science education. Located at Ohio State University, the national clearinghouse collects, catalogs, and disseminates information, curriculum materials, and other resources for K–12. At the state and local levels, regional consortia provide technical assistance and information to educators and policymakers. The service boundaries of the consortia are identical to those of the regional educational laboratories, which are involved in the consortium program.

Eisenhower National Clearinghouse
for Mathematics and Science Education
Len Simutis, director
Ohio State University
1929 Kenny Rd.
Columbus, OH 43210
(614) 292-7784

Eisenhower Math/Science Consortium.
at Appalachia Education Laboratory
Pam Buckley, director
1031 Quarrier St. P. O. Box 1348
Charleston, WV 25325
(304) 347-0400

Serves Kentucky, Tennessee, Virginia, West Virginia

Far West Eisenhower Regional Consortium
for Mathematics and Science Education
Art Sussman, director
730 Harrison St.
San Francisco, CA 94107
(415) 565-3070

Serves Arizona, California, Nevada, and Utah

High Plains Consortium for Mathematics and Science
2550 South Parker Rd. Suite 500
John Sutton, director
Aurora, CO 80014
(303) 337-0990

Serves Colorado, Kansas, Missouri, Nebraska, North Dakota, South Dakota, Wyoming

Mid-Atlantic Regional Consortium for Mathematics and Science Education
Keith Kershner, director
444 North Third St.
Philadelphia, PA 19123
(215) 574-9300

Serves Delaware, District of Columbia, Maryland, New Jersey, Pennsylvania

Midwest Consortium for the Systemic Reform of Mathematics and Science Education
Gil Valdez, director
1900 Spring Rd., Suite 300
Oak Brook, IL 60521
(708) 571-4700

Serves Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, Wisconsin

Northwest CMAST: Northwest Consortium for Mathematics and Science Teaching
Rob Larson, director
101 SW Main St., Suite 500
Portland, OR 97204-3297
(503) 275-9594

Serves Alaska, Idaho, Montana, Oregon, Washington

Pacific Mathematics and Science Regional Consortium
Rick Davis, director
828 Fort St. Suite 500
Honolulu, HI 96813
(808)533-6000

Serves American Samoa, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Guam, Hawaii, Republic of the Marshall Islands, Republic of Palau

Regional Alliance for Systemic Mathematics and Science Education Reform of the Northeast and Islands
Bob McLaughlin, co-director
235 Main St.
Montpelier, VT05602
(802) 223-0463

Eileen Ferrance, co-director
300 Brickstone Square, Suite 900
Andover, MA 01810
(508) 475-0098

Serves Connecticut, Maine, Massachusetts, New Hampshire, New York, Puerto Rico, Rhode Island, Vermont, Virgin Islands

Southeastern Mathematics and Science Regional Consortium
Francena Cummings, director
345 S. Magnolia Dr., Suite D-23
Tallahassee, FL 32301
(904) 922-8533

Serves Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina

Southwest Consortium for the Improvement of Mathematics and Science Teaching
Wes Hoover, director
211 East Seventh St.
Austin, Texas 78701
(512) 476-6861

Serves Arkansas, Louisiana, New Mexico, Oklahoma, Texas

Southwest Consortium
for the Improvement
of Mathematics and
Science Teaching

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